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**THE AVIAN REPRODUCTION STUDY: DISTRIBUTION OF  
THE CONTROL DATA AND STATISTICAL POWER ANALYSES**

**B.T. Collins**

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100 Gamelin Blvd.  
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## **Summary:**

This report is divided in two parts:

Part A presents an analysis of the control data obtained from a number of reproductive tests conducted in Mallard ducks and Bobwhite quail. These tests, were carried out to an EPA protocol mandated by the U.S. and a number of other countries for the purpose of pesticide registration. This protocol is currently the subject of study. The goal of this exercise was to describe the distribution of endpoints for a control population so as to test the statistical power of the reproduction test through simulations of reproductive effects (Part B).

Part B looks at the ability of several statistical tests to detect effects on egg laying, eggshell cracking and hatching rate. Eight different 'effect scenarios' with test results for three dose levels were generated and used in the power tests. Based on these results, it can be concluded that:

- The number of cages currently specified in the protocol is grossly insufficient. The sample size required is different for the three variables studied and notably higher to detect an effect on egg laying.
- Increasing the test from 8 to 12 weeks reduces the power of the test for measuring hatching effects.
- Of the tests considered, Williams's test is generally the most efficient with Bartholomew's test a close second.
- The choice of caging design is not straightforward. Particularly in the Mallard, the decision to adopt a 1♂:1♀ design may result in a substantial loss of power over a 2:5 design. Cost, the number of pens available, concern over the number of animals used in the test and the type of reproductive effects expected are factors that should be considered.

## **Résumé:**

*Ce rapport est divisé en deux sections:*

*La section A analyse la distribution des données de groupes témoins obtenues lors de tests visant à évaluer les effets sur la reproduction du Mallard et du Colin de Virginie. Ces tests sont présentement mandatés par l' EPA américain et d'autres agences d'homologation de pesticides à travers le monde et font présentement le sujet d'une étude approfondie. Le but de cet exercice était de décrire la distribution des variables clefs d'une population contrôlée de façon à pouvoir explorer l'efficacité de plusieurs méthodes statistiques utilisées pour déceler l'effet d'un pesticide ou toute autre substance chimique sur la reproduction des oiseaux (section B).*

*La section B passe en revue plusieurs tests statistiques utilisés pour déceler un effet sur la ponte, sur la proportion d'oeufs fêlés ou sur le taux d'éclosion selon 8 scénarios différents d'effets précis en réponse à une série de trois doses graduées. D'après les résultats obtenus, nous pouvons conclure que:*

- *Le nombre de cages présentement utilisé est nettement insuffisant. Les trois variables étudiées requièrent des tailles d'échantillonnage différentes; et déceler un effet sur la ponte exige de plus grands effectifs.*
- *Une augmentation de la durée du test de 8 à 12 semaines diminue l'efficacité du test en ce qui a trait aux mesures du taux d'éclosion.*
- *Des tests étudiés, le test de William est le plus efficace suivi du test de Bartholomew.*
- *La façon dont les oiseaux sont répartis dans les cages est une décision qui ne peut être prise à la légère particulièrement chez le mallard où la décision de former des groupes de 1♂:1♀, plutôt que 2:5, peut mener à une nette perte d'efficacité statistique. Les coûts, le nombre de cages disponibles, la volonté de réduire le nombre d'animaux utilisés ainsi que le genre d'effets escomptés sont des facteurs qui devraient être pris en considération.*

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**PART A: DISTRIBUTION OF THE  
CONTROL DATA**

## 1) INTRODUCTION

The overall goal of this project is to examine the statistical power of the avian reproduction test and make recommendations on sample size. Part A examines the distribution of the data obtained from several actual avian reproduction (AR) studies. The objective of Part A is to develop models for the distribution of avian reproduction data. The distributional models are necessary as a first step in evaluating the statistical power of the avian reproduction test. The models presented in Part A will be used in a subsequent simulation study (Part B).

In addition it is possible to compare the distributions among various experimental protocols. Although the conclusive comparisons will be done through the power simulations, direct comparisons of the distributions of study endpoints derived from different protocols are useful in selecting which protocols should be evaluated further. Those protocols which result in more variable results can be anticipated to be less powerful. These preliminary evaluations of the differences will be compared with the results of the power calculations.

A total of 49 AR studies were obtained in which the observations taken each week on test were available. This is a subset of the AR studies analysed by Mineau *et al.* (1994). This enabled an examination of the effect of the length of the experiment on the results. The current standards for AR studies leave several aspects of the experimental design open to the discretion of the experimenter. These include the number of weeks on test and the number of males and females in each cage. The two species used in AR studies are the Bobwhite Quail and the Mallard. Bobwhite Quail studies have been run in two manners of caging: i) one male and one female per cage and ii) one male and two females per cage. The mallard studies also have been run using two caging techniques: i) one male and one female and ii) two males and five females per cage. The number of studies in each combination of caging and duration is shown in Table 1.

The experimental design involves a control group and several graded dietary levels of a test compound. It is common to have 6 cages in each of the control and treatment groups for mallard studies and 12 cages in Bobwhite quail studies. The appropriate number of males and females are randomly assigned to cages and treatments. The birds are acclimatized to the diets and the light cycle is adjusted to maintain the birds in reproductive quiescence. This is called the pre-egg laying period of the study. The length of this period varies at the discretion of the experimenter. After the acclimatization period the photoperiod is increased and the egg-laying period commences. The number of eggs laid and the fate of these eggs is followed for the duration of the experiment. In addition the condition of the adults in the cage is monitored.

The number of eggs laid in each cage each week is counted. The number of

cracked eggs is noted and all cracked eggs are removed. A sample of the non-cracked eggs is then removed for eggshell measurements. The remaining eggs are 'set' i.e. placed in an incubator and the number of these eggs which hatch is recorded. For the hatched chicks the number which survive to 14 days is recorded. Unfortunately once the chicks hatch they are no longer separated by pen. In addition the weight of the adults, the food consumption per pen and the weight of the chicks is recorded.

This report is restricted to an analysis of the number of eggs laid and the fate of the eggs up to hatching. Five variables were analyzed: i) number of eggs laid, ii) proportion of non-cracked eggs, iii) proportion of eggs set which hatch, iv) estimated proportion of eggs laid which hatch, and v) estimated number of eggs which hatch.

This report is divided into the following sections. Section 2 sets out the mathematical notation necessary to describe the problem. In Section 3, some simple graphical summaries of the data are presented. The need to partition the variability into within and among pen variance dictates the type of analysis which is appropriate for the data. The presence and magnitude of the among pen variance is analyzed in Section 4. Once the presence of interpen variability has been established, the best estimate of the mean for each treatment group is a weighted average of the results from individual pens. Several alternative weighting schemes are examined in section 5. In section 6 a model is fitted to selected protocols. This model provides a base from which simulation studies on the power of the AR test can be based.

## 2) NOTATION

This section sets out the notation used to describe the data collected in an AR study. Further notation will be introduced as necessary throughout the paper.

For the  $j$ -th pen in treatment  $i$  define

$b_{ij}$  = number of eggs laid

$c_{ij}$  = number of non-cracked eggs

$d_{ij}$  = number of eggs set

$e_{ij}$  = number of eggs which hatch

From the above observed variables the following variables can be calculated

$$C_{ij} = \text{proportion of non-cracked eggs laid} \\ = c_{ij} / b_{ij} \\ (\text{undefined if } b_{ij}=0)$$

$$H_{ij} = \text{proportion of eggs set which hatch} \\ = e_{ij} / d_{ij} \\ (\text{undefined if } d_{ij}=0)$$

$$V_{ij} = \text{proportion of eggs laid which hatch} \\ = C_{ij} H_{ij} \\ (=0 \text{ if } C_{ij}=0)$$

$$T_{ij} = \text{estimated number of eggs laid which would hatch} \\ = b_{ij} V_{ij} \\ (=0 \text{ if } b_{ij}=0)$$

A subscript indicating week on test could be added to the above definitions but this would only make the notation more cumbersome. It will be clear from the context whether the discussion is based on the results from a single week or for a total over several weeks.

### 3) DESCRIPTIVE ANALYSIS

#### 3.1) Methods

In order to simplify the study of the effect of different study durations, some studies were set aside from the preliminary analysis. This was done to create a data set in which the comparisons among studies of different durations were not confounded with differences in experiments. Only experiments with at least 12 weeks of data were included for Bobwhite quail in 1:1 or 1:2 caging and mallards in 2:5 caging. All experiments with mallards in 1:1 caging were all of shorter duration than 12 weeks and any experiment with at least 8 weeks of data was included. If a study had more weeks than the minimum number the extra weeks of data were not included in the analysis. From Table 1 it can be seen that the selected studies include 3 experiments for Bobwhite quail in 1:1 caging, 7 experiments on Bobwhite quail in 1:2 housing, 13 experiments on mallards in 1:1 housing and 10 experiments on mallards in 2:5 housing.

The box plots proposed by Chambers et.al. (1983) were used to display the data for each variable, each week and each experimental design. These graphs are constructed as follows. A box is drawn with the upper and lower quartiles as limits. A line is drawn across this box at the median. Lines are drawn from the end of the box up and down to the adjacent value. Any observations farther from the median than the adjacent values are called outside values and marked with an asterisk. (There may be several coincident observations at each asterisk.) The

adjacent value is defined as follows. Define the interquartile range (IQR) as the distance between the upper and lower quartiles. The upper adjacent value is the largest observation which is less than or equal to the upper quartile plus 1.5 IQR. The lower adjacent value is defined similarly.

The box plots (Figures 1, 3, 5, 7 & 9) illustrate how the distribution of each variable changes with the week on test but the graphs from different weeks are correlated since the same pens are involved in each distribution. The total number of eggs laid, non-cracked, set and hatched were added over different periods of time by pen to illustrate the data which would be used in the statistical analysis. The totals for all possible 8, 9, 10, 11, and 12 week series of data were calculated. (This was not done for mallards in 1:1 caging since only an 8 week period was available.) For two variables: number of eggs laid and estimated number of eggs hatched, these totals were divided by the number of weeks on test to enable the box plots to be placed on one figure (Figures 2, 4, 6, 8 & 10). These boxes were grouped by the number of weeks in the total. Thus from left to right, the first 5 box plots show the totals over 8 week periods, the next 4 show totals over 9 week periods, the next 3 give totals over 10 week periods, the next 2 totals over 11 week period and the last one the total over the entire 12 week period.

### **3.2) Results**

#### **3.2.1) Eggs laid**

It can be seen (Figure 1) that for either bobwhite experiment the distribution of the number of eggs laid shifts toward larger values as the experiment progresses. The distribution becomes stable after 7 weeks on test. For 1:1 caging the IQR increases substantially after 10 weeks on test but this is not the case for birds in 1:2 caging. There were pens with zero eggs laid in each week.

For mallards (Figure 1) in 1:1 caging the number of eggs laid includes several large outliers in the first week. These observations must include eggs laid in the week prior to the egg-laying period. Except for these outliers the distribution of number of eggs laid shifts toward larger values until week 3 at which point the distribution remains stable up to week 6 after which the distribution shifts toward smaller values.

For mallards in 2:5 caging distribution of eggs laid shifts towards larger values up to week 4 and then remains stable up to week 7. After which egg production tends to decline.

The sum of the number of eggs laid over selected weeks on test is shown in Figure 2. For either Bobwhite quail experiment, if the number of weeks is held constant then the mean number of eggs laid exhibits a gradual increase as the starting

week of the summation increases. This is what would be expected from examining Figure 1. The interquartile range remains stable across all distributions. The upper quartile is slightly closer to the median than the lower quartile for 1:1 caging but the opposite is true for 1:2 caging. The lower adjacent value is always at zero for both caging types. For 1:1 caging the upper adjacent value is stable across all periods of summation but for 1:2 caging there is a consistent increase in the upper adjacent value within blocks of data averaged over the same number of weeks.

For mallards (Figure 2) the distribution of totals over selected appear to be more symmetric. The median is approximately halfway between the upper and lower quartile, and the upper and lower adjacent values are a similar distance from the median. All pens have some egg production although in many instances at least one pen is flagged as being an outside value on the low side.

### 3.2.2) Proportion of non-cracked eggs

The proportion of the eggs laid which were non-cracked is shown in Figure 3 by week. For Bobwhite quail in 1:1 caging the distribution is similar for all weeks. For Bobwhite quail in 1:2 caging a large proportion of the pens had no cracked eggs in weeks 1 and 2 but after the third week on test the distributions become quite similar. In both experiments at least 25% of the cages had no cracked eggs in any given week but cages in which all eggs were cracked occurred throughout the experiment.

For mallards (Figure 3) The distribution of the proportion of eggs cracked is similar across all weeks. Mallards in 1:1 caging often had 75% of the cages with no cracked eggs. (In this instance the interquartile range is zero and all values below the lower quartile are flagged as outside values.) The distribution is somewhat more stable than that for the Bobwhite quail with more than 50% cracked eggs being a rare event.

The totals over selected weeks are shown in Figure 4. For both species and both caging types for the Bobwhite quail the distributions are quite similar for all ranges of weeks considered. The median is either centred in the box or slightly closer to the upper quartile. For both species there are always observations with 100% non-cracked eggs and for the bobwhite quail in either caging there are always observations with all eggs cracked.

### 3.2.3) Proportion of eggs set which hatch

The proportion of the eggs set which hatch is shown in Figure 5 by week. For Bobwhite quail in either caging type all of the eggs in a pen hatch for at least 25% of the pens each week and some pens have no eggs which hatch each week. There

is no consistent pattern of change in the results over weeks on test. For mallards in 1:1 caging distribution of the proportion of non-cracked eggs shifts towards larger values as the experiment progresses. The distribution stabilizes after 4 weeks on test. For mallards in 1:2 caging the occurrence of pens with 100% non-cracked eggs is less frequent than for the other experiment types. The distribution shifts slightly towards larger values from week 1 to week 4 and remains stable thereafter up to week 9. The distribution then has a slight shift towards smaller values for the last weeks of the experiment.

The totals over selected weeks are shown in Figure 6. For both species the median of the distribution is generally slightly closer to the upper quartile. For Bobwhite quail in either caging type there are pens for which no eggs hatch and pens in which all eggs hatch in all summation periods. For mallard there are no extreme pens in which all or none hatch.

#### 3.2.4) Estimated proportion of eggs laid which hatch

The estimated proportion of eggs laid which hatch are shown by week in Figure 7. These variables are a product of the proportion of non-cracked eggs and the proportion of eggs set which hatch. For Bobwhite quail in either caging type there were pens which had 100% and others which had 0% hatched each week. For the first 2 or 3 weeks on test the interquartile range is relatively large compared to that for later weeks. For the mallard under 1:1 caging there were pens with 100% and pens with 0% hatched each week and the distribution of the proportion hatching shifts towards larger values as the experiment progresses. The distribution becomes stable after 5 weeks on test. For mallard in 2:5 caging there are pens with 0% hatched in each week and pens with 100% hatched in most weeks. There also is a tendency for the distribution to shift toward larger values for the first 3 or 4 weeks on test and then to stabilize. The interquartile range has a tendency to increase after 11 weeks on test.

The proportion of eggs which hatch based on sums over selected weeks is shown in Figure 8. For Bobwhite quail the median of the distribution is closer to the upper quartile. For Bobwhite quail in 1:1 caging there were cages in which 100% and those in which 0% hatch in each range of weeks. For Bobwhite quail in 1:2 caging there were observations in which 0% of the eggs hatched in each week but the interquartile range is smaller than that for the 1:1 caging experiment and these values are marked as outside values. For mallards the median is sometimes closer to the upper quartile and sometimes closer to the lower quartile. The interquartile range is smaller than that for the Bobwhite Quail studies.

#### 3.2.5) Estimated number of eggs laid which hatch

The estimated number of eggs which hatch is shown in Figure 9. For Bobwhite

quail in either caging type the distribution of the estimated number of eggs which hatch gradually shifts toward larger values for the first 6 weeks on test and then becomes stable for the rest of the experiment. In general the median is closer to the upper quartile than to the lower one. For mallards in 1:1 caging the distribution shifts towards larger values as the experiment progresses becoming stable after 4 weeks on test. The median is closer to the upper quartile than the lower one. For mallards in 2:5 caging the distribution shifts towards larger values for the first four weeks, remains stable up to week 7 and by week 8 has begun to shift towards lower values.

The totals over selected weeks are shown in Figure 10. For Bobwhite Quail in 1:1 caging the median is closer to the upper quartile of the distribution. Within each set of totals based on the same number of weeks the distribution shifts towards larger values as the initial week increases and the interquartile range increases. For Bobwhite quail in 1:2 caging the median is close to midway between the upper and lower quartile. Otherwise the distributions are similar to those for 1:1 caging. For mallards in 2:5 caging, the median is near to the midpoint between the upper and lower quartiles and the interquartile range declines as the number of weeks included in the average increases.

#### 4) VARIANCE COMPONENTS

For the proportion variables, proportion of non-cracked eggs and the proportion of eggs which hatch, one can partition the variance into two components: among and within pen variance. The presence of an among pen variance component implies that a proper statistical analysis must take this variance term into account. Ignoring this component will tend to underestimate the variability inherent in the data and result in reporting treatment effects to be significant too often.

Estimates of the within pen ( $s_w^2$ ) and among pen variance ( $s_a^2$ ) were calculated for the proportion of non-cracked eggs and the proportion of set eggs which hatch. The estimates were made separately for each experiment using a standard ANOVA procedure for unbalanced designs (Sokal and Rohlf, 1981). The estimated among pen variance was set equal to zero whenever the estimate was negative. The intrapen correlation was calculated as

$$s_w^2 / (s_w^2 + s_a^2)$$

and the estimated fraction of the variance which could be ascribed to intrapen correlation at an average sample size was calculated as

$$s_w^2 / (s_w^2 + s_a^2 / n_0)$$

where  $n_0$  is defined in Sokal and Rohlf (1981, p297).

The p-value for the test of significance of the among pen variance was coded as follows

\*  $0.01 < p < 0.05$

\*\*  $0.001 < p < 0.01$

\*\*\*  $p < 0.001$

The estimated among pen and within pen variances, the intrapen correlation coefficient and the among pen variance expressed as a fraction of the variance of the pen mean are shown in Tables 2 and 3 for the proportion of non-cracked eggs and the proportion of cracked eggs which hatch respectively.

In one experiment with Bobwhite quail, no eggs were cracked and the variance components were both zero. For the remaining experiments, the among pen variance was set equal to zero 5 times in the 34 bobwhite quail experimental designs and 9 times in the 34 mallard experimental designs. The among pen variance was significant ( $p < 0.05$ ) 25 and 15 times for the bobwhite quail and mallard respectively. Because the data are zero-one variables the appropriateness of the test is open to doubt. However, the test was highly significant ( $p < 0.001$ ) 18 times for the bobwhite quail and twice for the mallard and it is likely that such values would remain significant under the appropriate test.

The intrapen correlation is small in most instances (less than 0.1 in all but 4 cases). This correlation, however, indicates the relative importance of the among pen variance in the pen mean for pens with one egg but the analysis is based on substantially larger numbers of eggs per pen. When the among pen variance is expressed as a fraction of the variance of the pen mean for a typical number of eggs per pen, it can be seen to be an important component of the variance. The among pen variance as a fraction of the variance of the pen mean is above 0.50 in 23/35 and 14/34 instances for bobwhite quail and mallard respectively.

For the proportion of eggs set which hatch, the among pen variance was set to zero in only one instance for the 69 experimental designs for both species. The among pen variance was significant ( $p < 0.05$ ) in 64 of the 69 cases and highly significant ( $p < 0.001$ ) in 53 instances. The intrapen correlation was somewhat larger than that for proportion of non-cracked eggs but was relatively small. Expressing the among pen variance as a fraction of the variance of the pen mean indicated it was an important component of the variance. The fraction was above 0.50 in 61 of 69 cases.

## 5) WEIGHTING

For the proportion variables the estimates of the proportion for each pen are based on different numbers of observations, hence the precision of the estimate varies among pens. The estimated proportions in each pen are averaged to yield the overall estimate of the mean proportion for the treatment group. Because the precision varies among pens, a more precise overall estimate can be calculated by using a weighted average of the individual pen means. The weighted average gives more weight to the pens where the estimate is more precise. Several alternative schemes have been proposed to weight the data so the weighted average of the pen means is an efficient estimator (Cochran, 1943; Birkes et.al., 1980). These types of weighting schemes have been compared for mammalian reproductive studies which have substantially smaller number of observations per pen (or litter) than are seen in the avian reproductive study. This section compares alternate weighting schemes for AR studies. Define the following terms:

$\sigma_w^2$  denote the within pen variance,  
 $s_w^2$  denote the estimated within pen variance,  
 $\sigma_a^2$  denote the among pen variance,  
 $s_a^2$  denote the estimated among pen variance,  
 $m$  denote the number of pens and  
 $n_i$  denote the number of observations in pen  $i$ .

Six weighting schemes were considered:

i) Optimum Weighting:

$$w(O)_i = n_i / ((n_i - 1)c(O) + 1)$$

$$\text{where } c(O) = \sigma_a^2 / (\sigma_a^2 + \sigma_w^2)$$

ii) Variance Estimate Weighting:

$$w(V)_i = n_i / ((n_i - 1)c(V) + 1)$$

$$\text{where } c(V) = s_a^2 / (s_a^2 + s_w^2)$$

iii) Equal Weighting:

$$w(E)_i = 1$$

iv) Binomial Weighting:

$$w(B)_i = n_i$$

v) Partial Weighting:

$$w(P)_i = n_i \text{ if } n_i < n(1/3) \\ = n(1/3) \text{ otherwise}$$

where  $n(1/3)$  is the smallest  $n_i$  greater than  $1/3$  of the  $n_i$

vi) Maximin variance weighting:

$$w(M)_i = n_i / ((n_i - 1)c(M) + 1)$$

where  $c(V)$  is the solution to the equation

$$n \sum_{i=1}^m n_i [(n_i - 1) c(V) + 1]^{-2} = m \sum_{i=1}^m n_i^2 [(n_i - 1) c(V) + 1]^{-2}$$

vii) Discard weighting:

$$w(D)_i = 1 \text{ if } n_i > 10 \\ = 0 \text{ otherwise}$$

Optimum weighting gives the most efficient estimate of the population mean. The relative efficiency of an estimator is defined as the variance of the estimator divided by the optimum variance (Cochran, 1943). Since the underlying variances are unknown it was impossible to calculate the true efficiency of each estimator. The efficiencies were estimated by substituting the estimated variances in place of the true variances. The relative efficiency of the variance estimation method could not be estimated using this technique since it would always equal 1.0 but for the other five procedures the estimated relative efficiencies are shown in Tables 4 and 5.

The two smallest efficiencies were noted for each scheme. The smallest efficiencies were seen with equal weighting (0.284 and 0.306) and were substantially smaller than the smallest values noted under other schemes. The extremely low efficiencies occurred when there was at least one pen with a small number in the denominator of the estimate. In these instances the pens with few observations had a large variance and averaging them with the other observations gave an overall estimate with a large variance. The discard weighting was introduced to

overcome this problem by discarding observations with large variance. The two smallest efficiencies observed with this scheme are (0.595 and 0.716) which are substantial improvements over equal weighting scheme but they remain substantially smaller than those seen with other weighting schemes.

The efficiencies of the remaining three weighting schemes in Tables 4 and 5 were compared and the results are summarized in Table 6. (Note numbers in the columns cannot be summed because of ties.) It can be seen that Binomial weighting was the least efficient in 106 out of 137 instances. Maximin was the most efficient in 82 instances. The two smallest estimated efficiencies for each weighting scheme are (0.794, 0.822) for binomial weighting, (0.865, 0.929) for partial weighting and (0.893, 0.919) for maximin weighting.

Of the 5 weighting schemes evaluated, maximin weighting appears to be the most efficient with partial weighting a possible second choice. The two schemes along with variance estimate weighting should be considered for further study.

## 6) FITTED DISTRIBUTIONS

This section will be concerned with fitting distributions to the observed variables so that simulation studies on the power of different designs can be examined. For each experimental design 3 variables: i) number of eggs laid, ii) proportion of non-cracked eggs and iii) proportion of non-cracked eggs which hatch were analyzed. The remaining 2 variables: estimated proportion of eggs laid which hatch and estimated number of hatched eggs can be derived from the other 3 variables.

Distributions were fitted to the data for Bobwhite Quail and Mallards for both caging types used for each species. Data were fitted for 8 week and 12 week study periods. Except for mallard in 1:1 caging for which no data was available for 12 weeks on test. These two time periods were selected as typical values for experiments of this type which have been run.

Since it is recommended in many statistical texts that transforming proportional data usually improves the fit of the data to the normal distribution the proportional data were transformed in the interest of developing a simple model which could be used to generate data for the simulations. The data were transformed using the logit transformation with values at 0.0 and 1.0 adjusted to allow the calculations to be carried out, i.e.

$$y = \ln(g/(1-g))$$

where  $g = 1/4n$  if  $p=0.0$   
 $= p$  if  $0.0 < p < 1.0$   
 $= 1-1/4n$  if  $p=1.0$

where  $p$  is the observed probability and  $n$  the denominator used in calculating the probability.

The Freeman-Tukey transformation was also considered as a possible choice for transformation but it would be difficult to calculate the inverse of this transformation. Calculating the inverse transformation is necessary for the planned simulation study and this transformation was not considered further.

The number of eggs laid and each of the two proportions were analyzed using a weighted MANOVA in which each variable had a different weight. Details of the model are given in Appendix 1. The reciprocal of the variance of the  $e_{ij}$  was the weighting term. Since the intrapen correlation was unknown and the sample size within each experiment was too small to provide a reliable estimate for each experiment, an overall estimate was calculated by adding the estimates of within and among pen variance for each experiment (Tables 2 and 3) and calculating the total among pen variance divided by the total of both variances. This estimate was used for all experiments and transformations (within an experimental design).

Q-Q plots of the adjusted among and within experiment residuals were made for each variable and a set of bivariate scatter plots among the different variables were made for the experiment means and the residuals.

The number of pens and experiments used for curve fitting for each design are shown in Table 7.

### 6.1) Bobwhite quail, 1:1 caging, 8 weeks

From Table 7 it can be seen that there were initially 304 observations from 18 experiments in the data set. There were 21 pens with either no eggs laid or no eggs set. These observations were set aside from the weighted MANOVA. Q-Q plots of the within and among experiment residuals are shown in Figure 11. In examining the within experiment residuals the plots appear to be straight lines except for the proportion hatched in which there appear to be 5 outliers. These observations were set aside. There is not enough data available to make an evaluation of whether the among experiment residuals did not follow a normal distribution.

The model was fitted to the remaining observations and the resulting MANOVA table is shown in Table 8. The univariate ANOVA tables (not shown here) indicated the among experiment effects were highly significant for all variables.

Scatter plots of the among and within experiment residuals are shown in Figures 12 and 13 respectively. There are no unusual values seen on the pairwise plots.

### **6.2) Bobwhite quail, 1:1 caging, 12 weeks**

From table 7 it can be seen there were originally 60 observations from 3 experiments in the data set. There were 3 pens with either no eggs laid or no eggs set. These observations were set aside from the weighted MANOVA. Q-Q plots of the within and among experiment residuals are shown in Figure 14. Examining the residuals revealed one outlier for proportion hatched and that the residuals for eggs laid did not appear to yield a straight line. For eggs laid the upper portion of the curve is curved downward suggesting that it is difficult for even highly productive birds to keep up a large egg production for 12 weeks. To counteract this the two pens with the smallest residuals were deleted along with the pen which was an outlier for proportion hatched. The weighted MANOVA was rerun and new QQ plots were made, Figure 15. In this graph all within experiment residuals appear to be straight lines. The results of the revised MANOVA are given in Table 9.

Scatter plots of the within experiment residuals are shown in Figure 15. No unusual values are apparent in the plots.

### **6.3) Bobwhite quail, 1:2 caging, 8 weeks**

There were originally 105 pens from 7 experiments in the data set. Two pens had no eggs laid and were set aside from the MANOVA. Q-Q plots of the within and among experiment residuals are shown in Figure 17. Examining the residuals suggested there were 3 residuals for proportion hatched and one for proportion non-cracked. These observations were deleted and the MANOVA was rerun. The results of the revised MANOVA are given in Table 10.

Scatter plots of the residuals are shown in Figure 18. No unusual values are apparent.

### **6.4) Bobwhite quail, 1:2 caging, weeks 1-12**

There were originally 105 pens from 7 experiments in the data set. Two pens had no eggs laid and were set aside from the MANOVA. Q-Q plots of the within and among experiment residuals are shown in Figure 19. Examining the residuals suggested there were 2 outliers for laid, one for proportion non-cracked and three for proportion hatched. These values were set aside and the MANOVA was rerun. The results of the revised MANOVA are given in Table 11. Scatter plots of the residuals are shown in Figure 20. No unusual values are apparent.

### **6.5) Mallard, 1:1 caging, weeks 1-8**

There were originally 208 pens from 13 experiments in the data set. There were no eggs laid in 3 pens and no eggs set in another 4 pens. These 7 pens were set aside from the MANOVA. Q-Q plots of the within and among experiment residuals are shown in Figure 21. Examining the residuals plots indicated there were 6 outliers for laid, one for proportion non-cracked and three for proportion hatched. These observations were set aside and the MANOVA rerun. The QQ plots of the residuals from this run (not shown here) indicated there were two further outliers for proportion hatched. These observations were set aside and the MANOVA rerun. No further outliers were noted in the Q-Q plots. The results of the MANOVA are given in Table 12. Scatter plots of the residuals are shown in Figure 22. No aberrant values are apparent in this graph.

### **6.6) Mallard, 1:2 caging, weeks 1-8**

There were 65 pens from 11 experiments in the data set. There were eggs laid and eggs set for every pen. Q-Q plots of the residuals from the MANOVA are shown in Figure 23. There are no obvious outliers in the data. The results of the MANOVA are given in Table 13. Scatter plots of the within experiment residuals are shown in Figure 24. No unusual values can be seen in these plots.

### **6.7) Mallard, 1:2 caging, weeks 1-12**

There were 59 pens from 10 experiments in the data set. There were eggs laid and set for every pen. Q-Q plots of the residuals from the MANOVA are shown in Figure 25. There are no obvious outliers in the data. The results of the MANOVA are given in Table 14. Scatter plots of the within experiment residuals are shown in Figure 26. No unusual values can be seen in these plots.

## **7) CONCLUSIONS**

This report documents the initial steps taken in assessing the power of the Avian Reproduction study. The conclusions made are intermediate decisions taken to select the parameters to be studied in the subsequent power analysis.

i) From the graphical presentation of the distributions (Section 3), it can be seen that the number of eggs laid and the proportion of eggs which hatch tends to increase for the first few weeks on test until it becomes stable. However the graphs displaying the overall summaries including or discarding some of the initial weeks of egg laying didn't indicate that these initial weeks appreciably increased the variability of the data. Hence the resulting analyses were done using the data starting at the first week of egg laying.

ii) From the graphical presentations (Section 3) it was seen that generally for all variables the numbers and proportions become more variable after 8-10 weeks on test. This suggests that continuing the experiment to longer time frames will increase the variability of the data and thereby reduce the power of the test. Whether this increase in variability would overwhelm the precision caused by a larger number of eggs being laid and monitored is difficult to assess. It was decided to analyze data for an 8 week and 12 week time frames which were the typical protocols for these experiments.

iii) The proportion data was shown to have two sources of variability: within and among pen variability (Section 4). The among pen variability generally comprised more than 50% of the variability at the average pen size. Thus this component of variability must be taken into account in an analysis of the data.

iv) Accommodating the among pen variance component in the estimation is done through taking a weighted average of the proportions for individual pens. It was found that equal weighting resulted in a substantially less precise estimate than variance estimate weighting (Section 5).

v) A trivariate normal model was fitted to 7 protocols (Section 6). These fitted models will be used as a basis for studying the power of the AR study.

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# APPENDIX 1: Weighted MANOVA with Different Weights for Each Variable for a One-Way Type II Model

Consider the multivariate model

$$\underline{y}_{ij} = \underline{\mu} + \underline{\delta}_i + \underline{e}_{ij}$$

where

$\underline{y}_{ij}$  = vector of observations in pen  $j$  in experiment  $i$ ,

$\underline{\mu}$  = overall mean vector

$\underline{\delta}_i$  = vector of effects of experiment  $i$  (random) and

$\underline{e}_{ij}$  = error vector

where  $i=1,2,\dots,m$  and  $j=1,2,\dots,n_i$ .

The terms  $\underline{\delta}_i$  and  $\underline{e}_{ij}$  are independently distributed vectors of random variables with mean zero and variance-covariance matrices.

$$V(\underline{\delta}_i) = \Sigma_a$$

and

$$V(\underline{e}_{ij}) = U_{ij} \Sigma_e U_{ij}$$

where  $\Sigma_a$  and  $\Sigma_e$  are unknown and  $U_{ij}$  is a known diagonal matrix.

This model could be solved using the standard equations for a weighted multivariate analysis of variance except that each variable uses a different weight. Consider one variable at a time. The model for variable  $h$  can be written

$$y_{h,ij} = \mu_h + \delta_{h,i} + e_{h,ij}$$

where

$$V(\delta_{h,i}) = \sigma_{ah}^2$$

and

$$V(e_{h,ij}) = u_{h,ij}^2 \sigma_{eh}^2$$

$$= \sigma_{eh}^2 / w_{h,ij}$$

The ANOVA table for this model is

SOURCE	D.F.	SUM OF SQUARES	EXPECTED MEAN SQUARED ERROR
Among Expt.	m-1	$\sum w_{i.} (D_{h,i} - G_h)^2$	$\sigma_{eh}^2 + C_h \sigma_{ah}^2$
Within Expt.	n-m	$\sum w_{ij} (y_{h,ij} - D_{h,i})^2$	$\sigma_{eh}^2$

where

$$D_{h,i} = \frac{\sum_{j=1}^{n_i} w_{h,ij} y_{h,ij}}{w_{h,i.}}$$

$$G_h = \frac{\sum_{i=1}^m w_{h,i.} D_{h,i}}{w_{h,..}}$$

and

$$C_h = \frac{1}{m-1} \left[ w_{h,..} - \frac{\sum w_{h,i.}^2}{w_{h,..}} \right]$$

The within experiment residuals are defined as

$$f_{h,ij} = \text{SQRT}(w_{h,ij}) (y_{h,ij} - D_{h,i})$$

The among experiment residuals are defined as

$$d_{h,i} = \text{SQRT}(w_{h,i.}) (D_{h,i} - G_h)$$

The only portion of the multivariate ANOVA which is not solved by the equations for the univariate models is the covariance among the variables. Multiplying the within experiment residuals from two different variables and similarly multiplying two among experiment residuals provides a manner of partitioning the cross products into among and within experiment components. Presenting the partitioned cross products between variable h and variable k in an ANOVA table format gives

SOURCE	D.F.	SUM OF CROSS PRODUCTS	EXPECTED MEAN CROSS PRODUCT
Among Expt.	m-1	$\sum d_{h,i} d_{k,i}$	$B_{hk} \sigma_{ehk} + C_{hk} \sigma_{ahk}$
Within Expt.	n-m	$\sum f_{h,ij} f_{k,ij}$	$A_{hk} \sigma_{ehk}$

where

$$A_{hk} = 1 + \frac{1}{n-m} \sum_{i=1}^m \left[ \frac{\left( \sum_{j=1}^{n_i} \text{SQRT}(w_{hij} w_{kij}) \right)^2}{w_{hi.} w_{ki.}} - 1 \right]$$

$$B_{hk} = \left[ \sum_{i=1}^m \left( \left( w_{h..} w_{k..} / \text{SQRT}(w_{hi.} w_{ki.}) \right) - w_{k..} \text{SQRT}(w_{hi.}/w_{ki.}) - \right. \right. \\ \left. \left. w_{h..} \text{SQRT}(w_{ki.} / w_{hi.}) \right) \times \left( \sum_{j=1}^{n_i} \text{SQRT}(w_{hij} w_{kij}) \right) \right. \\ \left. + \left( \sum_{i=1}^m \text{SQRT}(w_{hi.} w_{ki.}) \right) \left( \sum_{i=1}^m \sum_{j=1}^{n_i} w_{hij} w_{kij} \right) \right] \frac{1}{(m-1) w_{h..} w_{k..}}$$

$$C_{hk} = \frac{1}{(m-1)w_{h..}w_{k..}} \left[ w_{h..}w_{k..} \sum_{i=1}^m \text{SQRT}(w_{hi.}w_{ki.}) - w_{k..} \sum_{i=1}^m \text{SQRT}(w_{hi.}^3 w_{ki.}) - w_{h..} \sum_{i=1}^m \text{SQRT}(w_{hi.}^3 w_{ki.}) + \left( \sum_{i=1}^m w_{hi.}w_{ki.} \right) \left( \sum_{i=1}^m \text{SQRT}(w_{hi.}w_{ki.}) \right) \right]$$

If the weights were the same for all variables i.e.  $w_{h,ij} = w_{k,ij}$  for all  $i$  and  $j$  then  $A_{hk} = B_{hk} = 1$  and  $C_{hk} = C_h$ . In general the weights will not be identical for different variables and the differences in weighting induces some complexity in the estimation of covariances. Unbiased estimated of the within and among experiment variances and covariances can be derived through linear combinations of the terms in the cross-products tables.

The complexity of the factors  $A_{hk}$  and  $B_{hk}$  preclude the use of standard MANOVA tests for the significance of the among experiment effects. The univariate analysis provide a test for the presence of experiment effects but the significance of the correlations among the within and among treatment effects cannot be tested without further theoretical work on the distribution of the test statistic.

Table 1: Frequency of occurrence of various design parameters in 49 historical studies

SPECIES	CAGING M:F	WEEKS ON TEST	NUMBER OF PENS	FREQUENCY
BOBWHITE QUAIL	1:1	8	16	2
		9	16	4
			17	1
		10	16	6
			20	1
		11	16	1
		12	20	3
	1:2	12	12	1
			14	3
			17	1
			20	1
		13	14	1
MALLARD	1:1	8	16	7
			17	1
		9	16	3
		10	16	2
	2:5	10	6	1
		12	5	1
			6	8
		13	6	1

Table 2: Estimated among pen variance, within pen variance intrapen correlation and relative fraction of intrapen variance at an average pen size for proportion of non-cracked eggs.

## BOBWHITE QUAIL WEEKS 1-8

CAGING	NUMBER OF PENS	ESTIMATED WITHIN PEN VARIANCE	ESTIMATED AMONG PEN VARIANCE		ESTIMATED INTRAPEN CORRELATION	ESTIMATED FRACTION OF AMONG PEN VAR. AT AVERAGE PEN SIZE
1:1	20	0.1620	0.0129	***	0.0739	0.7229
1:1	18	0.0758	0.0000		0.0000	0.0000
1:1	16	0.0360	0.0011	*	0.0292	0.4792
1:1	18	0.1229	0.0093	***	0.0701	0.7149
1:1	15	0.0720	0.0091	***	0.1125	0.8005
1:1	15	0.0611	0.0016		0.0248	0.3839
1:1	20	0.1002	0.0015		0.0147	0.2981
1:1	16	0.1075	0.0299	***	0.2174	0.9243
1:1	15	0.0284	0.0021	***	0.0698	0.7158
1:1	16	0.0309	0.0000		0.0000	0.0000
1:1	16	0.0367	0.0003		0.0091	0.2363
1:1	16	0.0316	0.0025	***	0.0721	0.7222
1:1	13	0.0106	0.0000		0.0000	0.0000
1:1	12	0.0388	0.0056	***	0.1271	0.8458
1:1	13	0.0139	0.0001		0.0097	0.2394
1:1	14	0.0000	0.0000		.	.
1:1	15	0.0242	0.0016	***	0.0605	0.6602
1:1	16	0.0250	0.0000		0.0000	0.0000
1:2	12	0.0954	0.0088	***	0.0841	0.7240
1:2	14	0.1530	0.0022	*	0.0143	0.4624
1:2	16	0.0865	0.0053	***	0.0573	0.6309
1:2	14	0.1314	0.0042	**	0.0310	0.6120
1:2	14	0.1168	0.0000		0.0000	0.0000
1:2	19	0.1169	0.0298	***	0.2030	0.8791
1:2	14	0.1189	0.0045	**	0.0362	0.6076

## BOBWHITE QUAIL WEEKS 1-12

1:1	20	0.1553	0.0077	***	0.0475	0.7163
1:1	18	0.0776	0.0018	**	0.0225	0.5126
1:1	19	0.1379	0.0101	***	0.0683	0.7984
1:2	12	0.0943	0.0066	***	0.0654	0.7602
1:2	14	0.1448	0.0040	***	0.0266	0.7323
1:2	16	0.1012	0.0069	***	0.0634	0.7595
1:2	14	0.1216	0.0033	***	0.0266	0.6978
1:2	14	0.1180	0.0014	*	0.0117	0.5123
1:2	19	0.1199	0.0275	***	0.1867	0.9166
1:2	14	0.1153	0.0021	**	0.0181	0.5727

Table 2 cont.

## MALLARD: WEEKS 1-8

CAGING	NUMBER OF PENS	ESTIMATED WITHIN PEN VARIANCE	ESTIMATED AMONG PEN VARIANCE		ESTIMATED INTRAPEN CORRELATION	ESTIMATED FRACTION OF AMONG PEN VAR. AT AVERAGE PEN SIZE
1:1	15	0.0238	0.0000		0.0000	0.0000
1:1	16	0.0491	0.0011	*	0.0229	0.5061
1:1	16	0.0540	0.0004		0.0069	0.1526
1:1	15	0.0172	0.0017	***	0.0910	0.8063
1:1	16	0.0186	0.0000		0.0000	0.0000
1:1	16	0.0143	0.0003	*	0.0192	0.4523
1:1	16	0.0284	0.0009	**	0.0303	0.5502
1:1	16	0.0240	0.0001		0.0047	0.1850
1:1	16	0.0399	0.0006		0.0145	0.3690
1:1	15	0.0218	0.0000		0.0000	0.0000
1:1	15	0.0428	0.0000		0.0000	0.0000
1:1	16	0.0188	0.0000		0.0000	0.0000
1:1	16	0.0457	0.0003		0.0057	0.2099
2:5	6	0.0531	0.0010	**	0.0189	0.7004
2:5	6	0.0728	0.0000		0.0000	0.0000
2:5	5	0.0433	0.0001		0.0018	0.2431
2:5	6	0.0440	0.0011	**	0.0247	0.6972
2:5	6	0.0338	0.0005	**	0.0153	0.7191
2:5	6	0.0309	0.0005	*	0.0147	0.5917
2:5	6	0.0574	0.0000		0.0008	0.0939
2:5	6	0.0365	0.0000		0.0000	0.0000
2:5	6	0.0650	0.0010	**	0.0155	0.6839
2:5	6	0.1235	0.0039	***	0.0307	0.8028
2:5	6	0.0555	0.0003		0.0051	0.3520

## MALLARD: WEEKS 1-12

2:5	6	0.0561	0.0009	**	0.0165	0.7117
2:5	6	0.0691	0.0001		0.0017	0.1655
2:5	5	0.0504	0.0004	*	0.0081	0.6635
2:5	6	0.0442	0.0006	**	0.0132	0.6791
2:5	6	0.0357	0.0005	**	0.0141	0.7175
2:5	6	0.0361	0.0001		0.0023	0.2677
2:5	6	0.0526	0.0001		0.0021	0.2424
2:5	6	0.0374	0.0000		0.0000	0.0000
2:5	6	0.0597	0.0008	**	0.0135	0.6945
2:5	6	0.0437	0.0001		0.0020	0.2553

Table 3 Estimated among pen variance, within pen variance and intrapen correlation and relative fraction of intrapen variance at an average pen size for proportion of eggs set which hatch.

## BOBWHITE QUAIL: WEEKS 1-8

CAGING	NUMBER OF PENS	ESTIMATED WITHIN PEN VARIANCE	ESTIMATED AMONG PEN VARIANCE		ESTIMATED INTRAPEN CORRELATION	ESTIMATED FRACTION OF AMONG PEN VAR. AT AVERAGE PEN SIZE
1:1	20	0.1475	0.0250 ***		0.1449	0.7932
1:1	18	0.1756	0.0522 ***		0.2294	0.8678
1:1	16	0.1261	0.0125 ***		0.0900	0.7160
1:1	18	0.1362	0.0097 ***		0.0664	0.6401
1:1	15	0.1061	0.0179 ***		0.1444	0.8085
1:1	15	0.1407	0.0152 ***		0.0976	0.6752
1:1	20	0.1185	0.0826 ***		0.4106	0.9424
1:1	16	0.1613	0.0461 ***		0.2223	0.9023
1:1	15	0.1353	0.0079 ***		0.0550	0.6238
1:1	16	0.1104	0.0029 *		0.0252	0.4262
1:1	16	0.0993	0.0083 ***		0.0774	0.7082
1:1	16	0.1803	0.0217 ***		0.1074	0.7759
1:1	12	0.1318	0.0080 **		0.0574	0.6218
1:1	12	0.1243	0.0100 ***		0.0747	0.7194
1:1	13	0.1710	0.0063 *		0.0357	0.5117
1:1	14	0.1394	0.0281 ***		0.1677	0.8075
1:1	15	0.1753	0.0345 ***		0.1646	0.8363
1:1	16	0.1665	0.0054 *		0.0315	0.4242
1:2	12	0.1734	0.0432 ***		0.1994	0.8187
1:2	14	0.1466	0.0152 ***		0.0942	0.8128
1:2	16	0.1585	0.0478 ***		0.2316	0.8688
1:2	14	0.1611	0.0563 ***		0.2590	0.9273
1:2	14	0.1742	0.0234 ***		0.1185	0.8385
1:2	19	0.2083	0.0422 ***		0.1684	0.8105
1:2	14	0.2106	0.0040		0.0189	0.3636

## BOBWHITE QUAIL: WEEKS 1-12

1:1	20	0.1385	0.0375 ***		0.2131	0.9071
1:1	18	0.1707	0.0475 ***		0.2175	0.9108
1:1	19	0.1405	0.0219 ***		0.1347	0.8620
1:2	12	0.1773	0.0619 ***		0.2589	0.9119
1:2	14	0.1441	0.0167 ***		0.1040	0.8933
1:2	16	0.1592	0.0462 ***		0.2248	0.9126
1:2	14	0.1545	0.0533 ***		0.2564	0.9567
1:2	14	0.1594	0.0192 ***		0.1077	0.8909
1:2	19	0.1829	0.0528 ***		0.2240	0.9104
1:2	14	0.2088	0.0090 ***		0.0412	0.6912

Table 3 cont.

## MALLARD: WEEKS 1-8

CAGING	NUMBER OF PENS	ESTIMATED WITHIN PEN VARIANCE	ESTIMATED AMONG PEN VARIANCE		ESTIMATED INTRAPEN CORRELATION	ESTIMATED FRACTION OF AMONG PEN VAR. AT AVERAGE PEN SIZE
1:1	14	0.2174	0.0353	***	0.1397	0.8534
1:1	16	0.1504	0.0064	***	0.0410	0.6152
1:1	16	0.2086	0.0414	***	0.1658	0.8028
1:1	15	0.1844	0.0363	***	0.1646	0.8796
1:1	16	0.1306	0.0762	***	0.3684	0.9571
1:1	16	0.1392	0.0605	***	0.3028	0.9420
1:1	15	0.1566	0.0125	***	0.0739	0.7449
1:1	16	0.1761	0.0135	***	0.0710	0.7637
1:1	16	0.1335	0.0631	***	0.3207	0.9414
1:1	14	0.1597	0.0703	***	0.3054	0.9294
1:1	15	0.1517	0.0430	***	0.2210	0.9169
1:1	16	0.1938	0.0174	***	0.0822	0.7724
1:1	16	0.1789	0.0387	***	0.1779	0.8968
2:5	6	0.1750	0.0004		0.0021	0.1833
2:5	6	0.1866	0.0004		0.0020	0.1410
2:5	5	0.2385	0.0053	**	0.0217	0.7593
2:5	6	0.2351	0.0182	***	0.0719	0.8445
2:5	6	0.2280	0.0042	**	0.0181	0.7266
2:5	6	0.2235	0.0320	***	0.1252	0.9157
2:5	6	0.2330	0.0072	***	0.0298	0.7853
2:5	6	0.2455	0.0021		0.0086	0.3906
2:5	6	0.2129	0.0111	***	0.0494	0.8587
2:5	6	0.1664	0.0168	***	0.0918	0.9108
2:5	6	0.2449	0.0000		0.0000	0.0000

## MALLARD: WEEKS 1-12

2:5	6	0.1963	0.0021	*	0.0106	0.5753
2:5	6	0.2019	0.0042	**	0.0206	0.6744
2:5	5	0.2360	0.0121	***	0.0488	0.9079
2:5	6	0.2364	0.0170	***	0.0670	0.8987
2:5	6	0.2277	0.0070	***	0.0298	0.8259
2:5	6	0.2234	0.0320	***	0.1252	0.9471
2:5	6	0.2368	0.0074	***	0.0301	0.8051
2:5	6	0.2352	0.0041	*	0.0172	0.6673
2:5	6	0.2230	0.0095	*	0.0409	0.8583
2:5	6	0.2485	0.0014	**	0.0056	0.4227

Table 4: Estimated efficiency of alternate weighting schemes based on estimated variance components for proportion of non-cracked eggs

BOBWHITE QUAIL: WEEKS 1-8

CAGING	NUMBER OF PENS	EFFICIENCY UNDER DIFFERENT WEIGHTING SCHEMES				
		E	B	P	M	D
1:1	20	.965	.928	.992	.995	.953
1:1	18	.628	1.000	.933	.940	.828
1:1	16	.906	.967	.979	.999	.907
1:1	18	.690	.962	.990	1.000	.976
1:1	15	.992	.966	.988	.995	.992
1:1	15	.711	.979	.985	.984	.902
1:1	20	.745	.990	.983	.980	.888
1:1	16	.999	.942	.982	.986	.999
1:1	15	.913	.933	.972	.997	.913
1:1	16	.906	1.000	.958	.979	.906
1:1	16	.797	.991	.973	.981	.925
1:1	16	.957	.933	.964	.996	.934
1:1	13	.306	1.000	.865	.912	.808
1:1	12	.994	.931	.988	.987	.994
1:1	13	.882	.995	.977	.989	.936
1:1	14	*****	*****	*****	*****	*****
1:1	15	.944	.957	.977	.999	.922
1:1	16	.505	1.000	.945	.910	.838
1:2	12	.977	.869	.992	.987	.977
1:2	14	.964	.984	.991	1.000	.964
1:2	16	.981	.963	.994	.999	.981
1:2	14	.454	.954	.986	.998	.963
1:2	14	.924	1.000	.965	.982	.924
1:2	19	.993	.905	.963	.980	.955
1:2	14	.491	.970	.991	.996	.938

BOBWHITE QUAIL: WEEKS 1-12

1:1	20	.961	.924	.991	.994	.961
1:1	18	.732	.972	.993	.997	.939
1:1	19	.594	.966	.988	1.000	.984
1:2	12	.968	.865	.976	.985	.968
1:2	14	.994	.968	.998	.997	.994
1:2	16	.993	.953	.997	.995	.993
1:2	14	.381	.958	.992	.999	.979
1:2	14	.969	.987	.995	1.000	.969
1:2	19	.999	.924	.998	.982	.999
1:2	14	.331	.975	.991	.993	.970

Table 4: cont.

## MALLARD: WEEKS 1-8

CAGING	NUMBER OF PENS	EFFICIENCY UNDER DIFFERENT WEIGHTING SCHEMES				
		E	B	P	M	D
1:1	15	.286	1.000	.974	.948	.960
1:1	16	.998	.998	.999	1.000	.998
1:1	16	.839	.997	.935	.975	.866
1:1	15	.998	.973	.998	.996	.998
1:1	16	.967	1.000	.987	.992	.967
1:1	16	.989	.994	.998	1.000	.989
1:1	16	.824	.977	.993	.998	.958
1:1	16	.932	.999	.993	.991	.932
1:1	16	.944	.991	.990	.997	.944
1:1	15	.383	1.000	.902	.893	.855
1:1	15	.956	1.000	.996	.991	.956
1:1	16	.961	1.000	.978	.990	.961
1:1	16	.992	.999	.997	.999	.992
2:5	6	.995	.980	.997	.998	.995
2:5	6	.595	1.000	.966	.934	.595
2:5	5	.995	1.000	.996	.999	.995
2:5	6	.985	.970	.993	.998	.985
2:5	6	.999	.996	1.000	1.000	.999
2:5	6	.987	.980	.990	1.000	.987
2:5	6	.917	1.000	.987	.985	.917
2:5	6	.870	1.000	.929	.968	.870
2:5	6	.993	.980	.998	.999	.993
2:5	6	1.000	.999	1.000	1.000	1.000
2:5	6	.966	.996	.997	.998	.966

## MALLARD: WEEKS 1-12

CAGING	NUMBER OF PENS	EFFICIENCY UNDER DIFFERENT WEIGHTING SCHEMES				
		E	B	P	M	D
2:5	6	.993	.968	.996	.997	.993
2:5	6	.716	.995	.953	.964	.716
2:5	5	1.000	.999	1.000	1.000	1.000
2:5	6	.992	.975	.997	.998	.992
2:5	6	.999	.996	1.000	1.000	.999
2:5	6	.978	.998	.992	.998	.978
2:5	6	.918	.996	.989	.991	.918
2:5	6	.885	1.000	.937	.972	.885
2:5	6	.990	.973	.994	.998	.990
2:5	6	.984	.999	.999	.998	.984

Table 5: Efficiency of binomial weighting based on estimated variance components for proportion of eggs set which hatch.

## BOBWHITE QUAIL: WEEKS 1-8

CAGING	NUMBER OF PENS	EFFICIENCY UNDER DIFFERENT WEIGHTING SCHEMES				
		E	B	P	M	D
1:1	20	.964	.896	.984	.987	.893
1:1	18	.958	.888	.972	.980	.922
1:1	16	.960	.917	.991	.994	.937
1:1	18	.699	.958	.990	1.000	.938
1:1	15	.987	.948	.985	.993	.952
1:1	15	.821	.931	.979	1.000	.857
1:1	20	.986	.870	.936	.962	.927
1:1	16	.996	.884	.980	.973	.996
1:1	15	.555	.953	.984	.996	.933
1:1	16	.938	.987	.991	.998	.946
1:1	16	.929	.926	.985	.997	.932
1:1	16	.957	.911	.958	.991	.904
1:1	12	.964	.923	.986	.997	.964
1:1	12	.978	.942	.990	.995	.978
1:1	13	.936	.973	.988	1.000	.945
1:1	14	.725	.887	.983	.996	.961
1:1	15	.979	.908	.957	.984	.850
1:1	16	.664	.968	.983	.987	.893
1:2	12	.977	.822	.987	.971	.796
1:2	14	.996	.956	.990	.993	.996
1:2	16	.994	.905	.978	.981	.945
1:2	14	.890	.865	.984	.975	.977
1:2	14	.997	.949	.992	.991	.997
1:2	19	.987	.916	.987	.987	.871
1:2	14	.397	.989	.984	.968	.962

## BOBWHITE QUAIL: WEEKS 1-12

1:1	20	.993	.861	.984	.965	.957
1:1	18	.951	.871	.946	.972	.973
1:1	19	.764	.936	.974	.997	.973
1:2	12	.990	.794	.959	.952	.863
1:2	14	.999	.957	.991	.991	.999
1:2	16	.998	.915	.981	.980	.998
1:2	14	.883	.891	.958	.977	.979
1:2	14	.997	.949	.988	.989	.997
1:2	19	.998	.917	.996	.981	.998
1:2	14	.497	.959	.990	.999	.957

Table 5: cont.

## MALLARD: WEEKS 1-8

CAGING	NUMBER OF PENS	EFFICIENCY UNDER DIFFERENT WEIGHTING SCHEMES				
		E	B	P	M	D
1:1	14	.999	.964	.999	.994	.999
1:1	16	.998	.994	.999	1.000	.998
1:1	16	.983	.880	.993	.982	.846
1:1	15	.999	.965	.996	.994	.999
1:1	16	1.000	.970	.991	.993	1.000
1:1	16	1.000	.968	.992	.993	1.000
1:1	15	.977	.956	.983	.996	.977
1:1	16	.990	.971	.987	.997	.990
1:1	16	.998	.917	.976	.977	.947
1:1	14	.915	.854	.960	.968	.915
1:1	15	.999	.974	.982	.994	.999
1:1	16	.997	.973	.996	.997	.997
1:1	16	1.000	.989	.998	.998	1.000
2:5	6	.960	.998	.969	.994	.960
2:5	6	.668	.999	.983	.958	.668
2:5	5	1.000	.995	1.000	.999	1.000
2:5	6	.995	.940	.990	.989	.995
2:5	6	1.000	.997	1.000	1.000	1.000
2:5	6	.999	.955	1.000	.990	.999
2:5	6	.993	.963	.983	.995	.993
2:5	6	.942	.981	.976	.998	.942
2:5	6	.999	.968	.998	.994	.999
2:5	6	1.000	.994	1.000	.999	1.000
2:5	6	.928	1.000	.995	.985	.928

## MALLARD: WEEKS 1-12

CAGING	NUMBER OF PENS	EFFICIENCY UNDER DIFFERENT WEIGHTING SCHEMES				
		E	B	P	M	D
2:5	6	.985	.979	.994	1.000	.985
2:5	6	.917	.940	.984	.999	.917
2:5	5	1.000	.996	1.000	.999	1.000
2:5	6	.999	.943	.998	.988	.999
2:5	6	1.000	.995	1.000	.999	1.000
2:5	6	1.000	.973	.995	.994	1.000
2:5	6	.992	.953	.981	.993	.992
2:5	6	.982	.954	.993	.997	.982
2:5	6	.998	.958	.993	.992	.998
2:5	6	.989	.997	.997	1.000	.989

Table 6: Comparison of relative efficiencies among three weighting schemes.

Relative Efficiency		
Scheme	Best	Worst
Binomial	29	106
Maximin	82	11
Partial	37	21

Table 7: Number of pens and experiments used in fitting distributions.

SPECIES	CAGING M:F	WEEKS ON TEST	NUMBER OF OBS.	NUMBER OF OBS. WITH LAID>0 AND SET>0	NUMBER OF OBS. AFTER DISCARDING OUTLIERS
Bobwhite	1:1	8	304(18)	283(18)	278(18)
		12	60( 3)	57( 3)	54( 3)
	1:2	8	105( 7)	103( 7)	99( 7)
		12	105( 7)	103( 7)	97( 7)
Mallard	1:1	8	208(13)	201(13)	189(13)
	1:2	8	65(11)	65(11)	65(11)
		12	59(10)	59(10)	59(10)

- table entries show number of pens (experiments)

Table 8: MANOVA for Bobwhite Quail, 1:1 caging, total weeks 1-8

SOURCE	DF	MEAN SUM OF CROSS PRODUCTS MATRIX		
Among Expt.	17	$\begin{bmatrix} 360.765 & -37.7360 & 1.7086 \\ -37.7360 & 118.827 & 4.7738 \\ 1.70869 & 4.77385 & 15.2799 \end{bmatrix}$		
Within Expt.	260	$\begin{bmatrix} 176.616 & 8.51671 & 3.21307 \\ 8.51671 & 11.8202 & -0.049359 \\ 3.21307 & -0.049359 & 7.34735 \end{bmatrix}$		

EXPECTED MEAN SUM OF  
CROSS PRODUCTS MATRIX

$$\begin{bmatrix} \sigma_{e,1}^2 & 0.993\sigma_{e,12} & 0.993\sigma_{e,13} \\ 0.993\sigma_{e,12} & \sigma_{e,2}^2 & 0.999\sigma_{e,23} \\ 0.993\sigma_{e,13} & 0.999\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix} + \begin{bmatrix} 15.43\sigma_{a,1}^2 & 46.90\sigma_{a,12} & 36.62\sigma_{a,13} \\ 46.90\sigma_{a,12} & 142.71\sigma_{a,2}^2 & 111.40\sigma_{a,23} \\ 36.62\sigma_{a,13} & 111.40\sigma_{a,23} & 86.97\sigma_{a,3}^2 \end{bmatrix}$$

$$\begin{bmatrix} \sigma_{e,1}^2 & 0.999\sigma_{e,12} & 0.999\sigma_{e,13} \\ 0.999\sigma_{e,12} & \sigma_{e,2}^2 & 1.000\sigma_{e,23} \\ 0.999\sigma_{e,13} & 1.000\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix}$$

$$S_e = \begin{bmatrix} 176.616 & 8.51671 & 3.21307 \\ 8.51671 & 11.8202 & -0.049359 \\ 3.21307 & -0.049359 & 7.34735 \end{bmatrix}$$

Table 8 cont.

$$S_a = \begin{bmatrix} 11.934 & -0.7317 & -0.04108 \\ -0.7317 & 0.7498 & 0.042410 \\ -0.04108 & 0.042410 & 0.091205 \end{bmatrix}$$

$$\text{mean} = \begin{bmatrix} 32.2734 \\ 3.23364 \\ 1.65740 \end{bmatrix}$$

$$\text{intra-pen correlation} = \begin{bmatrix} 1.00000 \\ 0.07353 \\ 0.13415 \end{bmatrix}$$

OUTLIERS SET ASIDE DUE TO INCOMPLETE TRIVARIATE DISTRIBUTION

LAID=0 in 20/304 instances

LAID=1 and SET=0 in 1/284 instances

TRANSFORMED RESIDUALS FOR OUTLIERS

NUMBER	LAID	PROPORTION NON-CRACKED	PROPORTION HATCHED OVER SET
1	-15.0000	-1.47494	-8.2718
2	-13.7778	3.67521	-9.3871
3	-6.8000	0.38525	-13.0010
4	6.2000	0.61837	-11.0509
5	-21.8750	-0.16494	-9.3620

Table 9: MANOVA for Bobwhite Quail, 1:1 caging, total weeks 1-12

SOURCE	DF	MEAN SUM OF CROSS PRODUCTS MATRIX		
Among Expt.	2	$\begin{bmatrix} 948.775 & -177.034 & 89.5265 \\ -177.034 & 59.4015 & -35.3583 \\ 89.5265 & -35.3583 & 21.6479 \end{bmatrix}$		
Within Expt.	51	$\begin{bmatrix} 382.270 & -1.65382 & 13.5026 \\ -1.65382 & 9.36217 & 0.47083 \\ 13.5026 & 0.47083 & 7.25228 \end{bmatrix}$		

EXPECTED MEAN SUM OF  
CROSS PRODUCTS MATRIX

$$\begin{bmatrix} \sigma_{e,1}^2 & 0.994\sigma_{e,12} & 0.998\sigma_{e,13} \\ 0.994\sigma_{e,12} & \sigma_{e,2}^2 & 1.000\sigma_{e,23} \\ 0.998\sigma_{e,13} & 1.000\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix} + \begin{bmatrix} 17.98\sigma_{a,1}^2 & 67.30\sigma_{a,12} & 38.40\sigma_{a,13} \\ 67.30\sigma_{a,12} & 252.08\sigma_{a,2}^2 & 143.77\sigma_{a,23} \\ 38.40\sigma_{a,13} & 143.77\sigma_{a,23} & 82.01\sigma_{a,3}^2 \end{bmatrix}$$

$$\begin{bmatrix} \sigma_{e,1}^2 & 0.999\sigma_{e,12} & 1.000\sigma_{e,13} \\ 0.999\sigma_{e,12} & \sigma_{e,2}^2 & 1.000\sigma_{e,23} \\ 1.000\sigma_{e,13} & 1.000\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix}$$

$$S_e = \begin{bmatrix} 382.270 & -1.65382 & 13.5026 \\ -1.65382 & 9.36217 & 0.47083 \\ 13.5026 & 0.47083 & 7.25228 \end{bmatrix}$$

$$S_a = \begin{bmatrix} 31.5049 & -2.60586 & 1.97996 \\ -2.60586 & 0.19851 & -0.24922 \\ 1.97996 & -0.24922 & 0.17554 \end{bmatrix}$$

Table 9 cont.

mean=  $\begin{bmatrix} 52.7778 \\ 1.89445 \\ 1.36275 \end{bmatrix}$

intra-pen correlation=  $\begin{bmatrix} 1.00000 \\ 0.05028 \\ 0.19199 \end{bmatrix}$

OUTLIERS SET ASIDE DUE TO INCOMPLETE TRIVARIATE DISTRIBUTION

LAIID=0 in 3/60 instances

#### TRANSFORMED RESIDUALS FOR OUTLIERS

NUMBER	LAIID	PROPORTION NON-CRACKED	PROPORTION HATCHED OVER SET
1	-14.2000	0.93779	-10.2336
2	-52.5263	0.38073	0.5557
3	-53.5263	-0.57140	-0.4183

Table 10: MANOVA for Bobwhite Quail, 1:2 caging, total weeks 1-8

SOURCE	DF	MEAN SUM OF CROSS PRODUCTS MATRIX		
Among Expt.	6	$\begin{bmatrix} 2249.31 & -180.056 & 94.0661 \\ -180.056 & 20.6542 & 0.64949 \\ 94.0661 & 0.64949 & 12.6291 \end{bmatrix}$		
Within Expt.	92	$\begin{bmatrix} 277.320 & -1.33270 & 1.96779 \\ 1.96779 & 9.38859 & -1.92486 \\ 1.96779 & -1.92486 & 4.64408 \end{bmatrix}$		

EXPECTED MEAN SUM OF  
CROSS PRODUCTS MATRIX

$$\begin{bmatrix} \sigma_{e,1}^2 & 0.992\sigma_{e,12} & 0.995\sigma_{e,13} \\ 0.992\sigma_{e,12} & \sigma_{e,2}^2 & 0.999\sigma_{e,23} \\ 0.995\sigma_{e,13} & 1.000\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix} + \begin{bmatrix} 14.11\sigma_{a,1}^2 & 46.81\sigma_{a,12} & 31.80\sigma_{a,13} \\ 46.81\sigma_{a,12} & 155.58\sigma_{a,2}^2 & 105.62\sigma_{a,23} \\ 31.80\sigma_{a,13} & 105.62\sigma_{a,23} & 71.73\sigma_{a,3}^2 \end{bmatrix}$$

$$\begin{bmatrix} \sigma_{e,1}^2 & 0.999\sigma_{e,12} & 0.999\sigma_{e,13} \\ 0.999\sigma_{e,12} & \sigma_{e,2}^2 & 1.000\sigma_{e,23} \\ 0.999\sigma_{e,13} & 1.000\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix}$$

$$S_e = \begin{bmatrix} 277.320 & -1.33270 & 1.96779 \\ 1.96779 & 9.38859 & -1.92486 \\ 1.96779 & -1.92486 & 4.64408 \end{bmatrix}$$

$$S_a = \begin{bmatrix} 139.748 & -3.81774 & 2.88960 \\ -3.81774 & 0.072408 & 0.02437 \\ 2.88960 & 0.02437 & 0.11132 \end{bmatrix}$$

Table 10 cont.

mean=  $\begin{bmatrix} 41.3131 \\ 2.00103 \\ 1.05188 \end{bmatrix}$

intra-pen correlation=  $\begin{bmatrix} 1.00000 \\ 0.06260 \\ 0.15847 \end{bmatrix}$

OUTLIERS SET ASIDE DUE TO INCOMPLETE TRIVARIATE DISTRIBUTION

LAID=0 in 2/105 instances

TRANSFORMED RESIDUALS FOR OUTLIERS

NUMBER	LAID	PROPORTION NON-CRACKED	PROPORTION HATCHED OVER SET
1	-17.3333	-4.92899	-6.6201
2	4.6875	-0.47235	-9.7396
3	-0.7895	3.87849	-10.6045
4	18.2105	-9.92439	-1.9521

Table 11: MANOVA for Bobwhite Quail, 1:2 caging, total weeks 1-12

SOURCE	DF	MEAN SUM OF CROSS PRODUCTS MATRIX		
Among Expt.	6	$\begin{bmatrix} 7868.28 & -349.242 & 128.419 \\ -349.242 & 21.0369 & -6.30406 \\ 128.419 & -6.30406 & 6.93768 \end{bmatrix}$		
Within Expt.	90	$\begin{bmatrix} 523.460 & 0.82357 & 4.70418 \\ 0.82357 & 11.0350 & -0.19729 \\ 4.70418 & -0.19729 & 4.89041 \end{bmatrix}$		

EXPECTED MEAN SUM OF  
CROSS PRODUCTS MATRIX

$$\begin{bmatrix} \sigma_{e,1}^2 & 0.999\sigma_{e,12} & 1.000\sigma_{e,13} \\ 0.999\sigma_{e,12} & \sigma_{e,2}^2 & 1.000\sigma_{e,23} \\ 1.000\sigma_{e,13} & 1.000\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix} + \begin{bmatrix} 13.82\sigma_{a,1}^2 & 50.28\sigma_{a,12} & 30.98\sigma_{a,13} \\ 50.28\sigma_{a,12} & 183.12\sigma_{a,2}^2 & 112.75\sigma_{a,23} \\ 30.98\sigma_{a,13} & 112.75\sigma_{a,23} & 69.44\sigma_{a,3}^2 \end{bmatrix}$$

$$\begin{bmatrix} \sigma_{e,1}^2 & 1.000\sigma_{e,12} & 1.000\sigma_{e,13} \\ 1.000\sigma_{e,12} & \sigma_{e,2}^2 & 1.000\sigma_{e,23} \\ 1.000\sigma_{e,13} & 1.000\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix}$$

$$S_e = \begin{bmatrix} 523.460 & 0.82357 & 4.70418 \\ 0.82357 & 11.0350 & -0.19729 \\ 4.70418 & -0.19729 & 4.89041 \end{bmatrix}$$

$$S_a = \begin{bmatrix} 531.413 & -6.96275 & 3.99389 \\ -6.96275 & 0.05462 & -0.054163 \\ 3.99389 & -0.054163 & 0.029481 \end{bmatrix}$$

Table 11 cont.

mean=  $\begin{bmatrix} 71.3918 \\ 2.03762 \\ 1.12713 \end{bmatrix}$

intra-pen correlation=  $\begin{bmatrix} 1.00000 \\ 0.05972 \\ 0.17926 \end{bmatrix}$

OUTLIERS SET ASIDE DUE TO INCOMPLETE TRIVARIATE DISTRIBUTION

LAID=0 in 2/105 instances

#### TRANSFORMED RESIDUALS FOR OUTLIERS

NUMBER	LAID	PROPORTION NON-CRACKED	PROPORTION HATCHED OVER SET
1	-31.5833	-5.5152	-6.5821
2	-0.9375	-0.6904	-10.0890
3	-84.7143	-0.7280	-0.0840
4	-2.1579	6.1296	-12.4482
5	26.8421	-10.5092	-1.4821
6	-72.7857	-0.7920	-1.8082

Table 12: MANOVA for Mallard, 1:1 caging, total weeks 1-8

SOURCE	DF	MEAN SUM OF CROSS PRODUCTS MATRIX		
Among Expt.	12	$\begin{bmatrix} 481.100 & 51.5086 & 67.2436 \\ 51.5086 & 98.0780 & 5.70353 \\ 67.2436 & 5.70353 & 23.0570 \end{bmatrix}$		
Within Expt.	176	$\begin{bmatrix} 80.4875 & 3.62233 & 4.06867 \\ 3.62233 & 23.6470 & 0.12170 \\ 4.06867 & 0.12170 & 4.94980 \end{bmatrix}$		

EXPECTED MEAN SUM OF  
CROSS PRODUCTS MATRIX

$$\begin{bmatrix} \sigma_{e,1}^2 & 0.996\sigma_{e,12} & 1.000\sigma_{e,13} \\ 0.996\sigma_{e,12} & \sigma_{e,2}^2 & 0.998\sigma_{e,23} \\ 1.000\sigma_{e,13} & 0.998\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix} + \begin{bmatrix} 14.52\sigma_{a,1}^2 & 75.79\sigma_{a,12} & 31.32\sigma_{a,13} \\ 75.79\sigma_{a,12} & 396.53\sigma_{a,2}^2 & 163.55\sigma_{a,23} \\ 31.32\sigma_{a,13} & 163.55\sigma_{a,23} & 67.55\sigma_{a,3}^2 \end{bmatrix}$$

$$\begin{bmatrix} \sigma_{e,1}^2 & 1.000\sigma_{e,12} & 1.000\sigma_{e,13} \\ 1.000\sigma_{e,12} & \sigma_{e,2}^2 & 1.000\sigma_{e,23} \\ 1.000\sigma_{e,13} & 1.000\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix}$$

$$S_e = \begin{bmatrix} 80.4875 & 3.62233 & 4.06867 \\ 3.62233 & 23.6470 & 0.12170 \\ 4.06867 & 0.12170 & 4.94980 \end{bmatrix}$$

$$S_a = \begin{bmatrix} 27.5765 & 0.63182 & 2.01696 \\ 0.63182 & 0.18770 & 0.034129 \\ 2.01696 & 0.034129 & 0.26806 \end{bmatrix}$$

Table 12 cont.

mean=  $\begin{bmatrix} 42.2910 \\ 3.81397 \\ 1.06311 \end{bmatrix}$

intra-pen correlation=  $\begin{bmatrix} 1.00000 \\ 0.01273 \\ 0.19088 \end{bmatrix}$

OUTLIERS SET ASIDE DUE TO INCOMPLETE TRIVARIATE DISTRIBUTION

LAID=0 in 4/208 instances

LAID=(1,4,5) and SET=0 in 3/204 instances.

TRANSFORMED RESIDUALS FOR OUTLIERS

NUMBER	LAID	PROPORTION NON-CRACKED	PROPORTION HATCHED OVER SET
1	4.2667	-15.5056	1.7385
2	1.8750	5.8358	-13.5806
3	-1.3750	-3.9826	-13.0725
4	-25.8000	-7.3544	4.1780
5	-30.0625	-4.6425	5.6634
6	-25.0000	-5.6758	-8.2796
7	0.7857	4.8907	-11.4769
8	-28.2143	-1.7518	0.4237
9	-33.2143	-2.6824	-1.5500
10	-21.9333	5.3427	-0.8887
11	-1.6667	8.0470	-7.9949
12	1.5000	-2.6700	-8.2133

Table 13: MANOVA for Mallard, 2:5 caging, total weeks 1-8

SOURCE	DF	MEAN SUM OF CROSS PRODUCTS MATRIX		
Among Expt.	10	$\begin{bmatrix} 4695.96 & -63.7520 & 16.0731 \\ -63.7520 & 82.8352 & -34.7434 \\ 16.0731 & -34.7434 & 44.0710 \end{bmatrix}$		
Within Expt.	54	$\begin{bmatrix} 882.913 & -24.3027 & -0.20298 \\ -24.3027 & 23.4290 & -0.17187 \\ -0.20298 & -0.17178 & 4.99680 \end{bmatrix}$		

EXPECTED MEAN SUM OF  
CROSS PRODUCTS MATRIX

$$\begin{bmatrix} \sigma_{e,1}^2 & 0.997\sigma_{e,12} & 0.999\sigma_{e,13} \\ 0.999\sigma_{e,12} & \sigma_{e,2}^2 & 1.000\sigma_{e,23} \\ 0.999\sigma_{e,13} & 1.000\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix} + \begin{bmatrix} 5.91\sigma_{a,1}^2 & 39.62\sigma_{a,12} & 26.44\sigma_{a,13} \\ 39.62\sigma_{a,12} & 266.23\sigma_{a,2}^2 & 177.54\sigma_{a,23} \\ 26.44\sigma_{a,13} & 177.54\sigma_{a,23} & 118.42\sigma_{a,3}^2 \end{bmatrix}$$

$$\begin{bmatrix} \sigma_{e,1}^2 & 0.999\sigma_{e,12} & 1.000\sigma_{e,13} \\ 0.999\sigma_{e,12} & \sigma_{e,2}^2 & 1.000\sigma_{e,23} \\ 1.000\sigma_{e,13} & 1.000\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix}$$

$$S_e = \begin{bmatrix} 882.913 & -24.3027 & -0.20298 \\ -24.3027 & 23.4290 & -0.17187 \\ -0.20298 & -0.17178 & 4.99680 \end{bmatrix}$$

$$S_a = \begin{bmatrix} 645.438 & -0.99576 & 0.61560 \\ -0.99576 & 0.22314 & -0.19473 \\ 0.61560 & -0.19473 & 0.32995 \end{bmatrix}$$

$$\text{mean} = \begin{bmatrix} 123.046 \\ 2.99159 \\ 0.45320 \end{bmatrix}$$

$$\text{intra-pen correlation} = \begin{bmatrix} 1.00000 \\ 0.01355 \\ 0.03925 \end{bmatrix}$$

Table 14: MANOVA for Mallard, 2:5 caging, total weeks 1-12

SOURCE	DF	MEAN SUM OF CROSS PRODUCTS MATRIX		
Among Expt.	9	$\begin{bmatrix} 5185.31 & 55.4131 & -237.568 \\ 55.4131 & 24.7028 & -7.4033 \\ -237.568 & -7.40332 & 22.8957 \end{bmatrix}$		
Within Expt.	49	$\begin{bmatrix} 1750.45 & -30.0421 & -12.2816 \\ -30.0421 & 23.6745 & -0.26234 \\ -12.2816 & -0.26234 & 4.83502 \end{bmatrix}$		

EXPECTED MEAN SUM OF  
CROSS PRODUCTS MATRIX

$$\begin{bmatrix} \sigma_{e,1}^2 & 0.997\sigma_{e,12} & 0.999\sigma_{e,13} \\ 0.997\sigma_{e,12} & \sigma_{e,2}^2 & 0.999\sigma_{e,23} \\ 0.999\sigma_{e,13} & 0.999\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix} + \begin{bmatrix} 5.89\sigma_{a,1}^2 & 49.98\sigma_{a,12} & 26.68\sigma_{a,13} \\ 49.98\sigma_{a,12} & 424.36\sigma_{a,2}^2 & 226.29\sigma_{a,23} \\ 26.68\sigma_{a,13} & 226.29\sigma_{a,23} & 120.75\sigma_{a,3}^2 \end{bmatrix}$$

$$\begin{bmatrix} \sigma_{e,1}^2 & 0.999\sigma_{e,12} & 1.000\sigma_{e,13} \\ 0.999\sigma_{e,12} & \sigma_{e,2}^2 & 1.000\sigma_{e,23} \\ 1.000\sigma_{e,13} & 1.000\sigma_{e,23} & \sigma_{e,3}^2 \end{bmatrix}$$

$$S_e = \begin{bmatrix} 1750.45 & -30.0421 & -12.2816 \\ -30.0421 & 23.6745 & -0.26234 \\ -12.2816 & -0.26234 & 4.83502 \end{bmatrix}$$

$$S_a = \begin{bmatrix} 582.35 & 1.70962 & -8.4430 \\ 1.70962 & 0.00242 & -0.031557 \\ -8.4430 & -0.031557 & 0.14957 \end{bmatrix}$$

$$\text{mean} = \begin{bmatrix} 164.034 \\ 3.06440 \\ 0.03780 \end{bmatrix}$$

intra-pen correlation=

$$\begin{bmatrix} 1.00000 \\ 0.007511 \\ 0.04097 \end{bmatrix}$$

FIGURE 1: NUMBER OF EGGS LAID PER WEEK

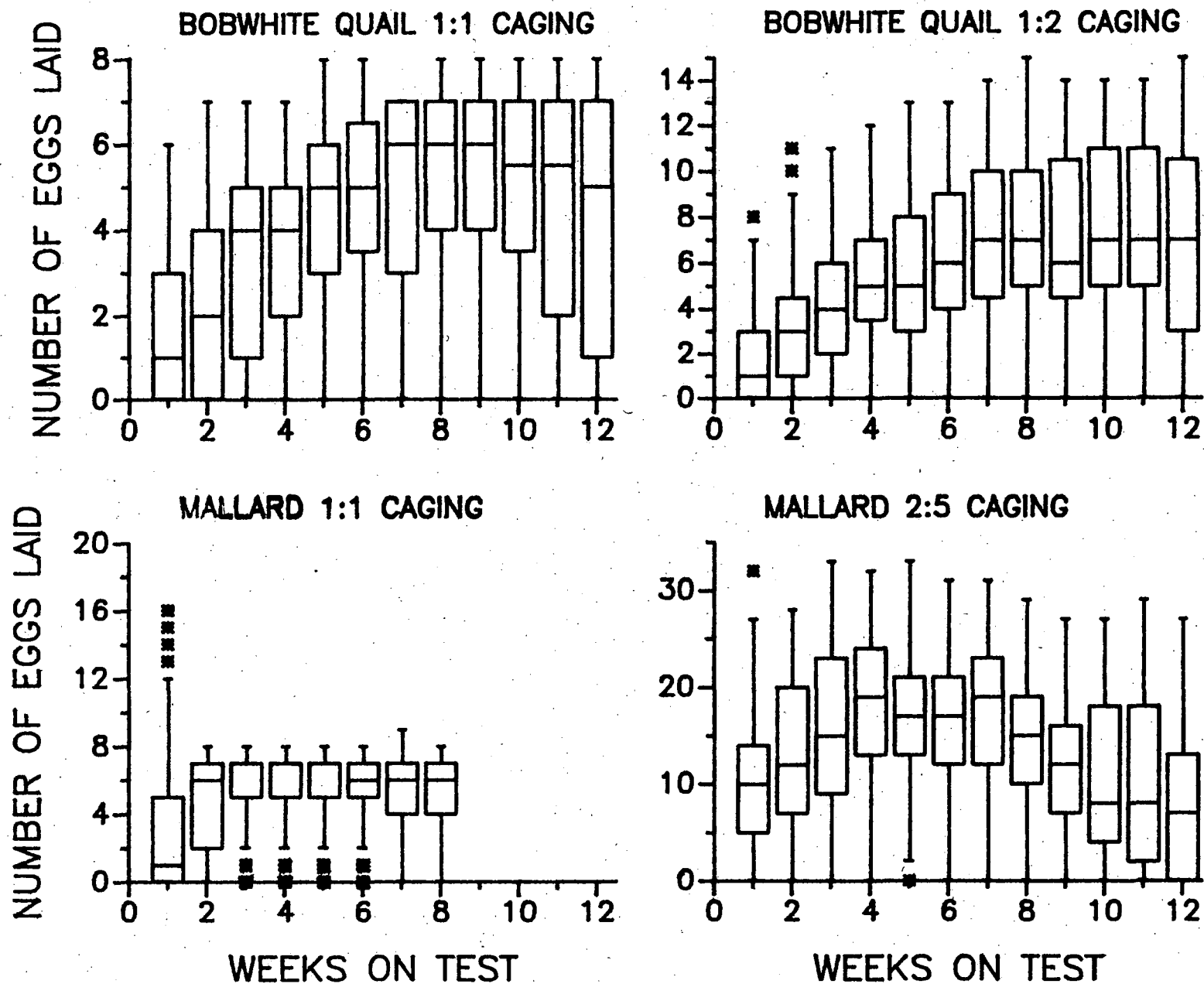


FIGURE 2: NUMBER OF EGGS LAID: TOTAL OVER  
SELECTED WEEKS  
BOBWHITE QUAIL 1:1 CAGING

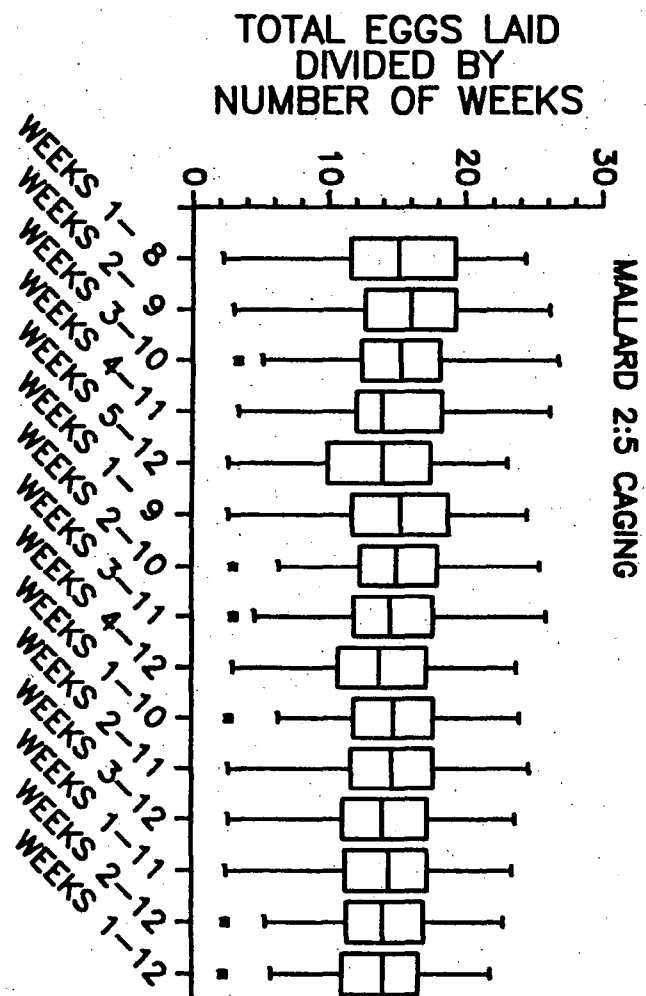
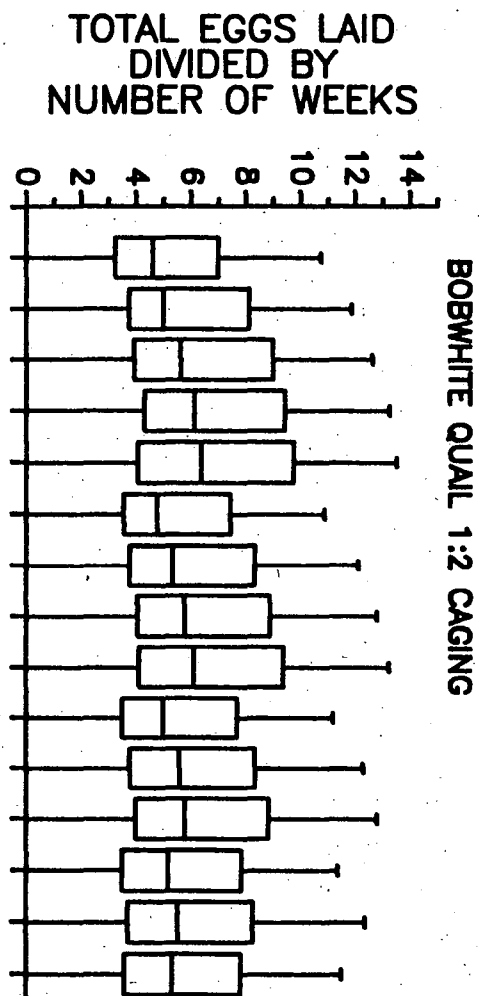
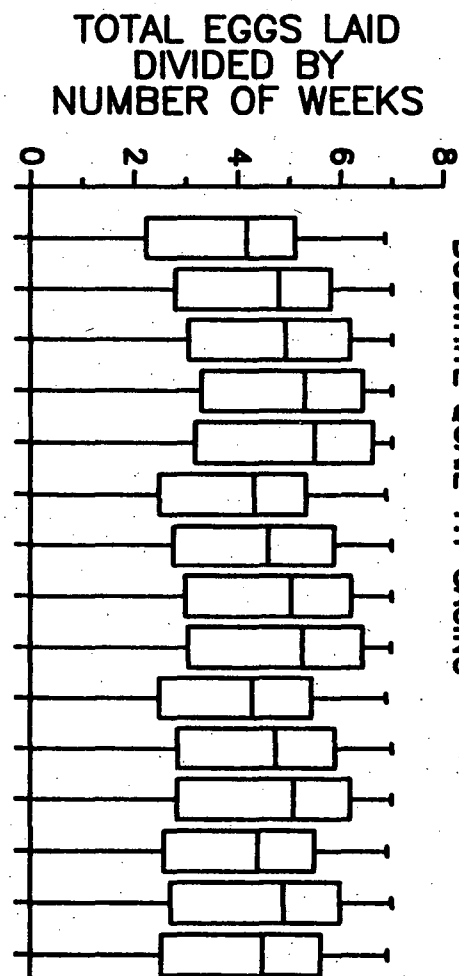


FIGURE 3: PROPORTION OF NON-CRACKED EGGS PER WEEK

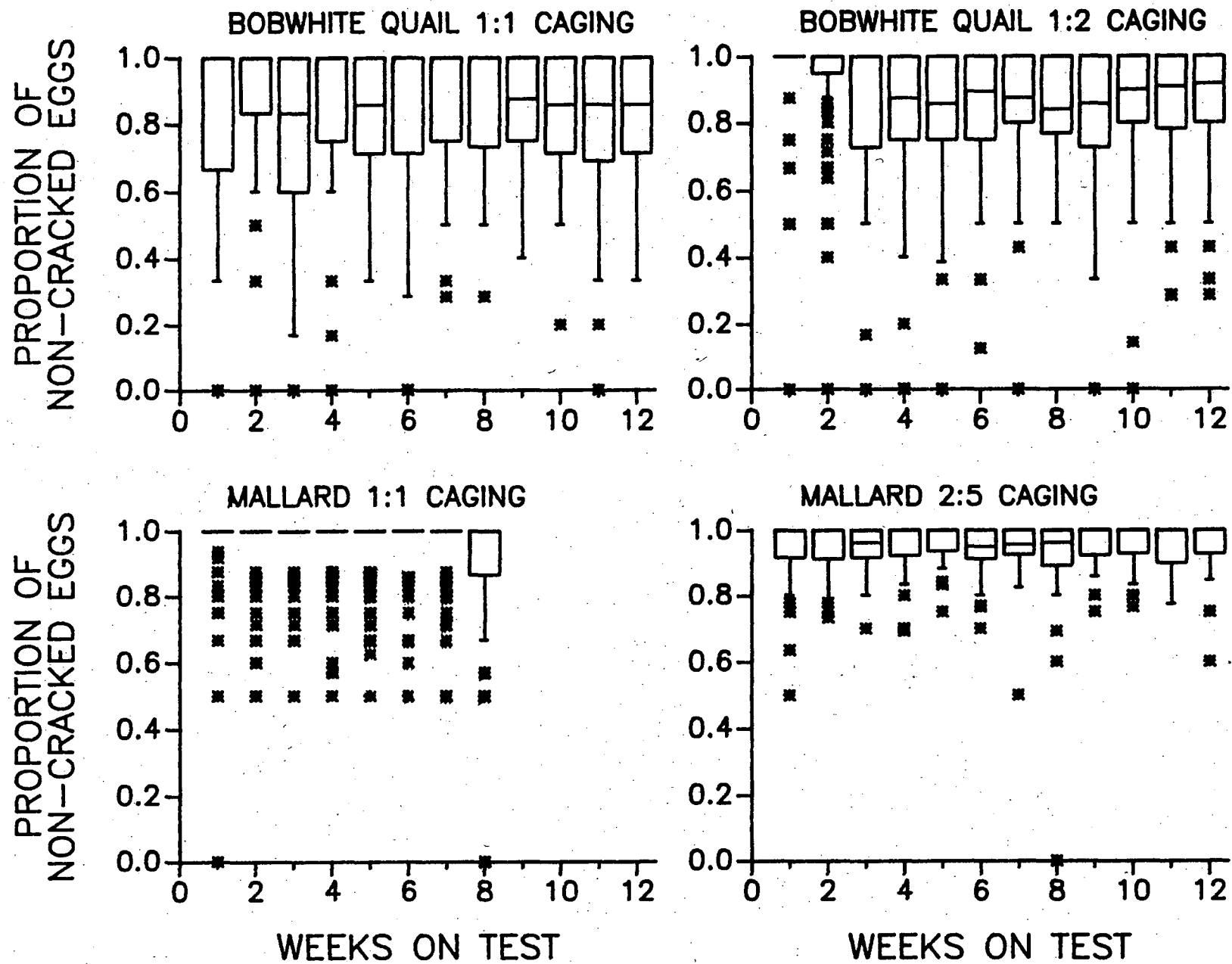


FIGURE 4: PROPORTION OF NON-CRACKED EGGS:  
TOTAL OVER SELECTED WEEKS

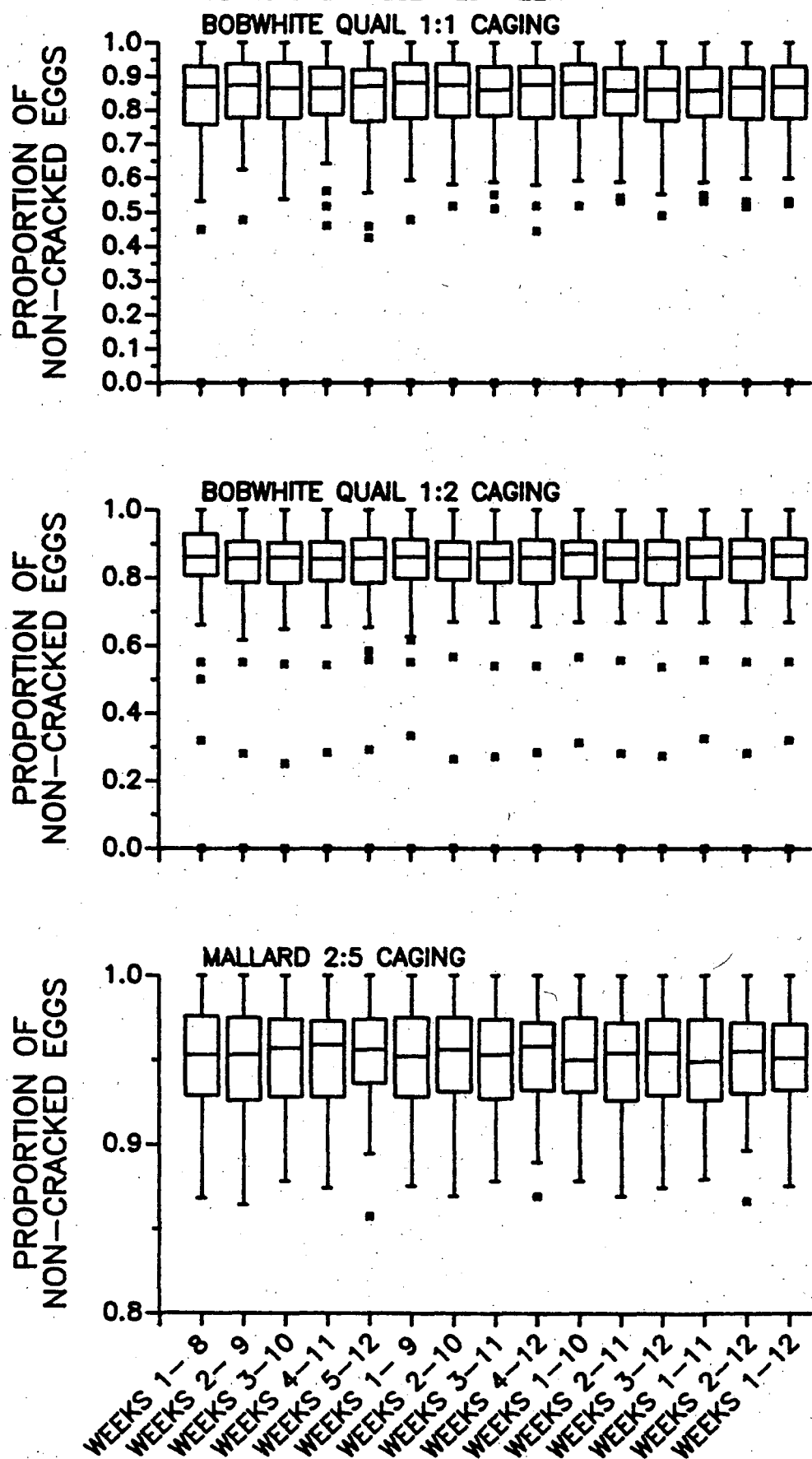
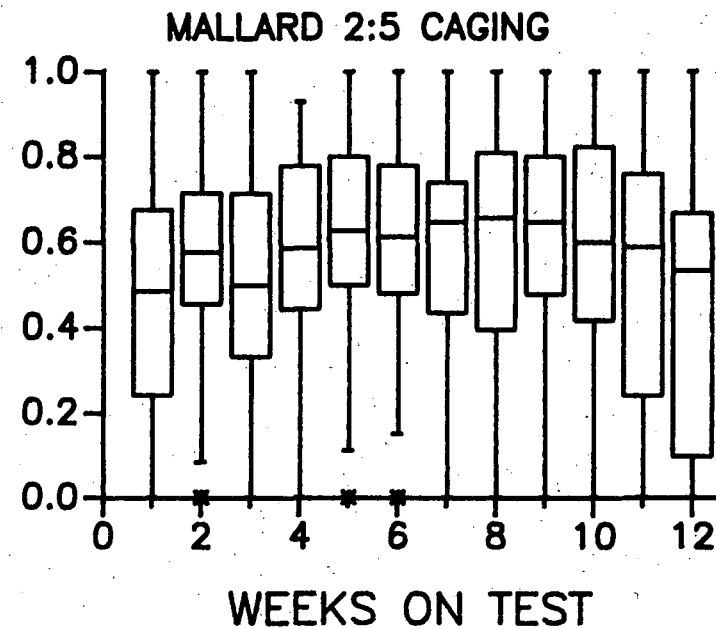
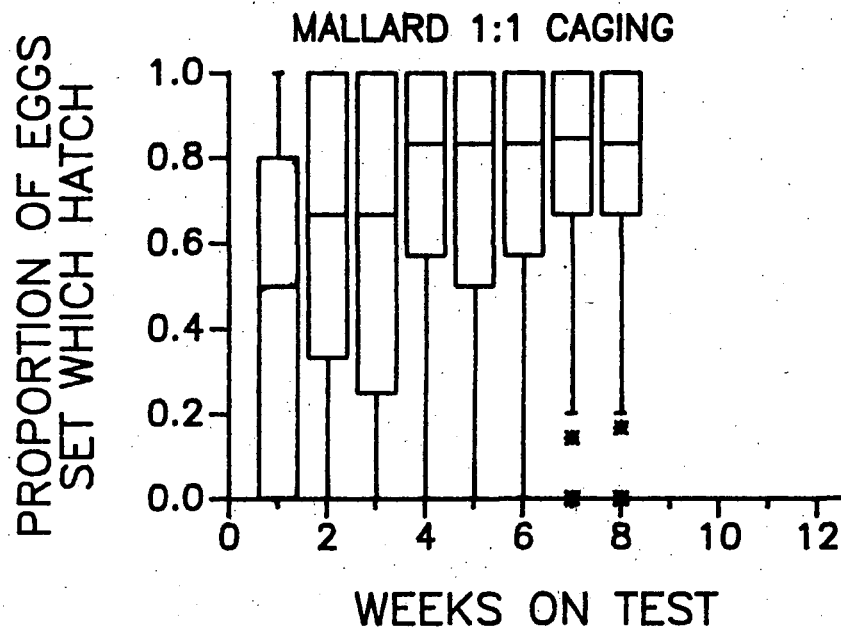
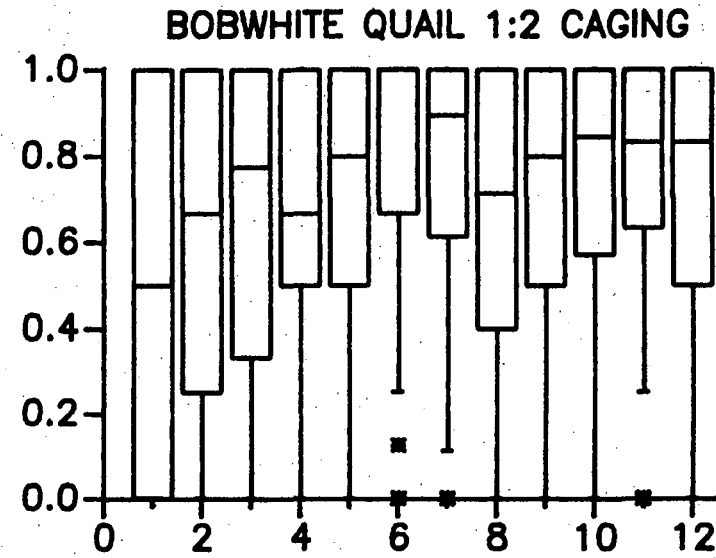
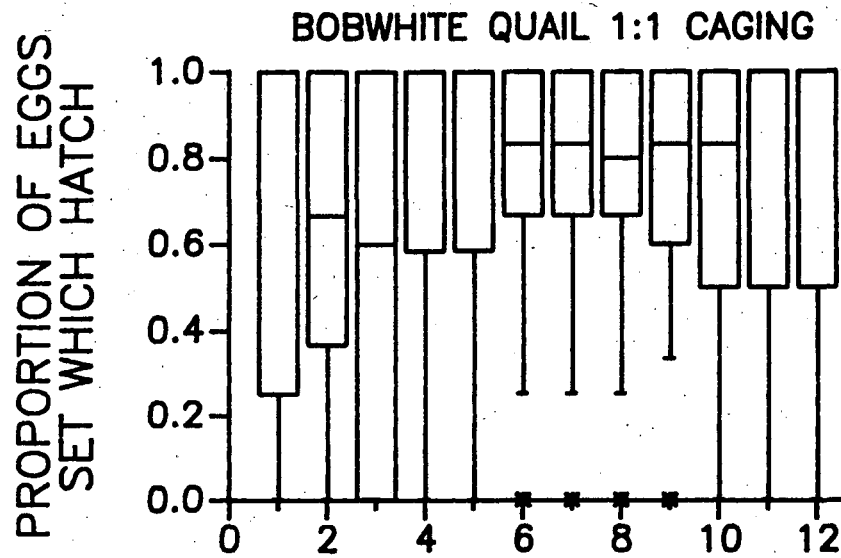


FIGURE 5: PROPORTION OF EGGS SET WHICH  
HATCH PER WEEK



**FIGURE 6: PROPORTION OF EGGS SET WHICH HATCH:  
TOTAL OVER SELECTED WEEKS**

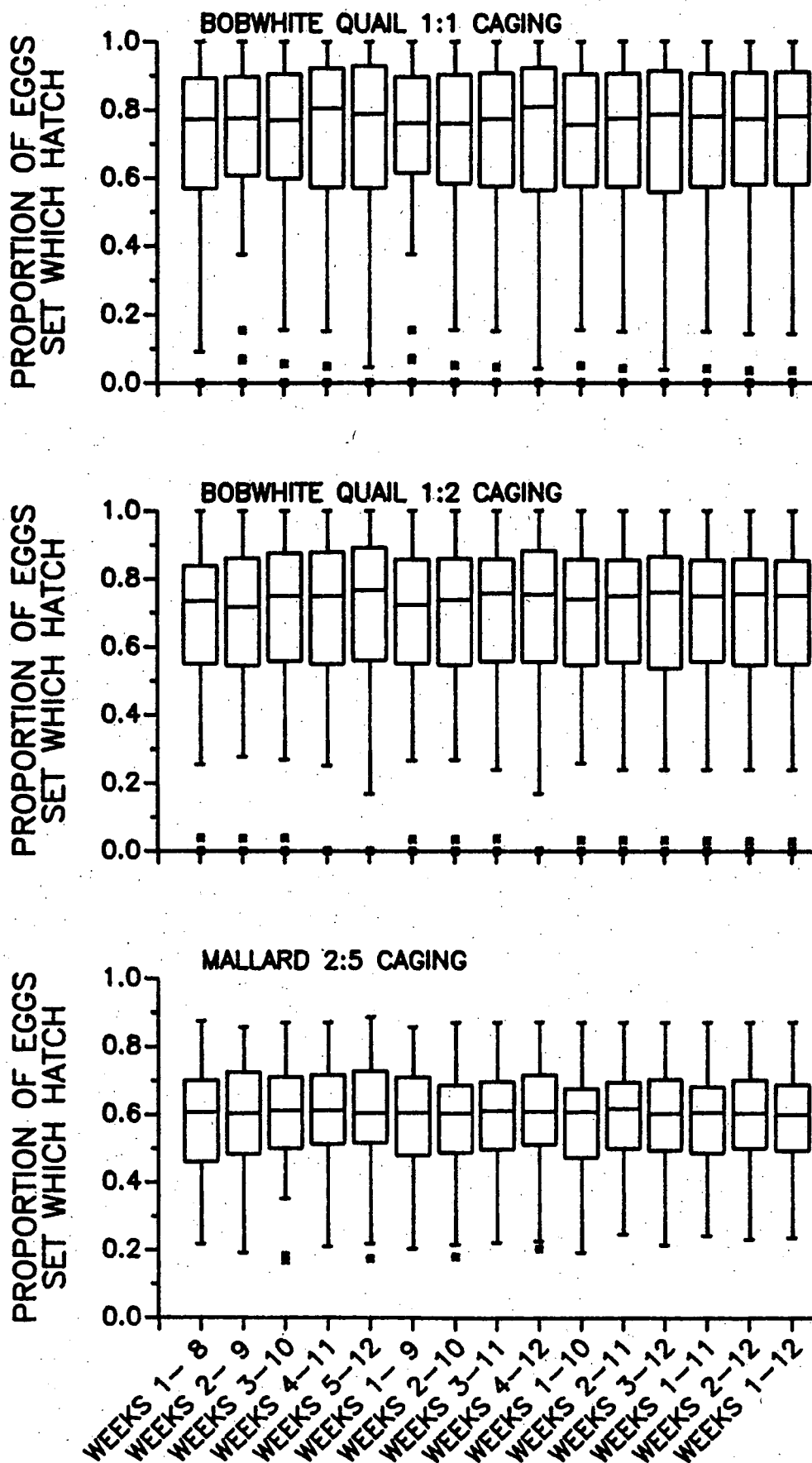
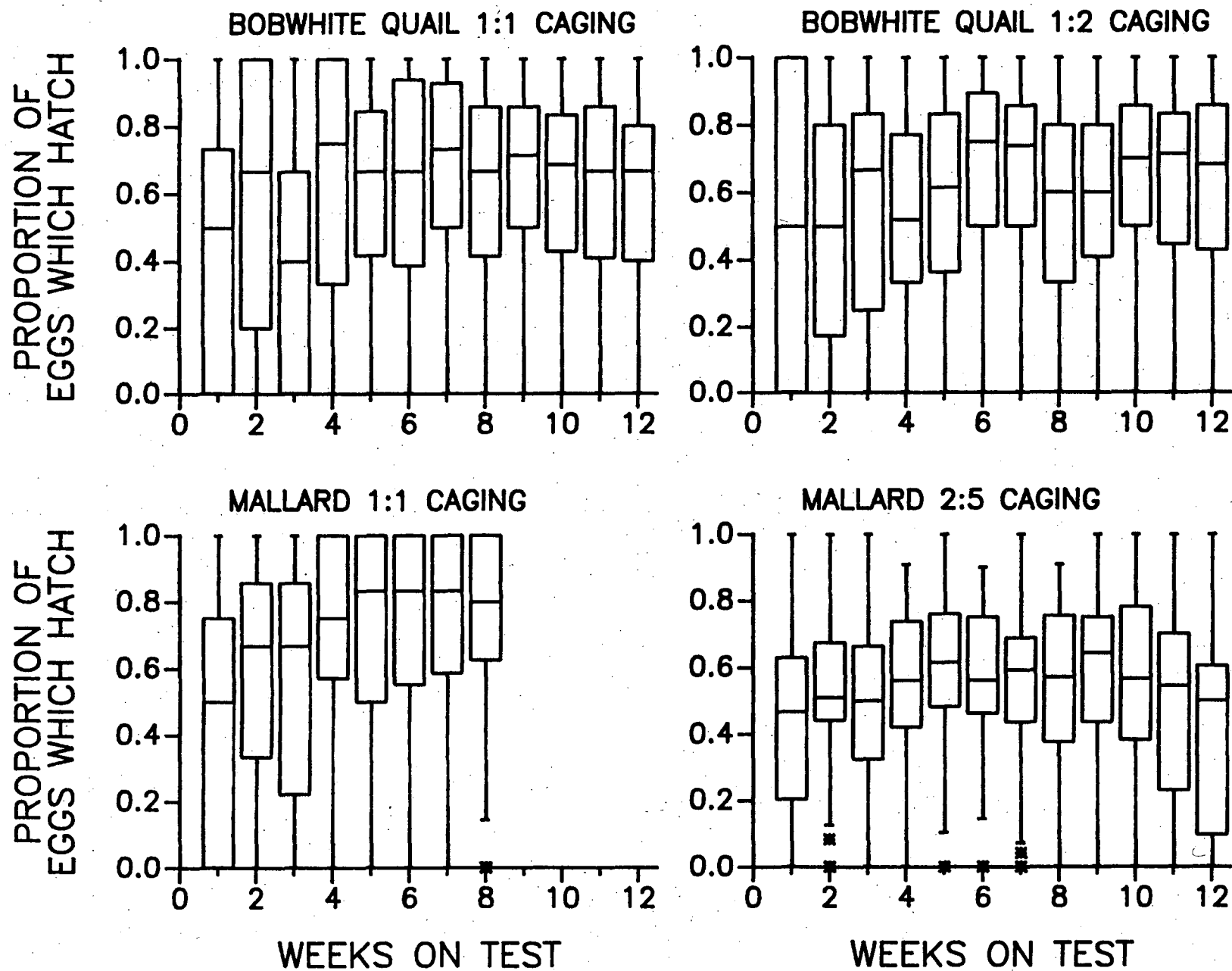


FIGURE 7: PROPORTION OF EGGS WHICH HATCH BY WEEK



**FIGURE 8: PERCENT OF EGGS WHICH HATCH:  
TOTAL OVER SELECTED WEEKS**

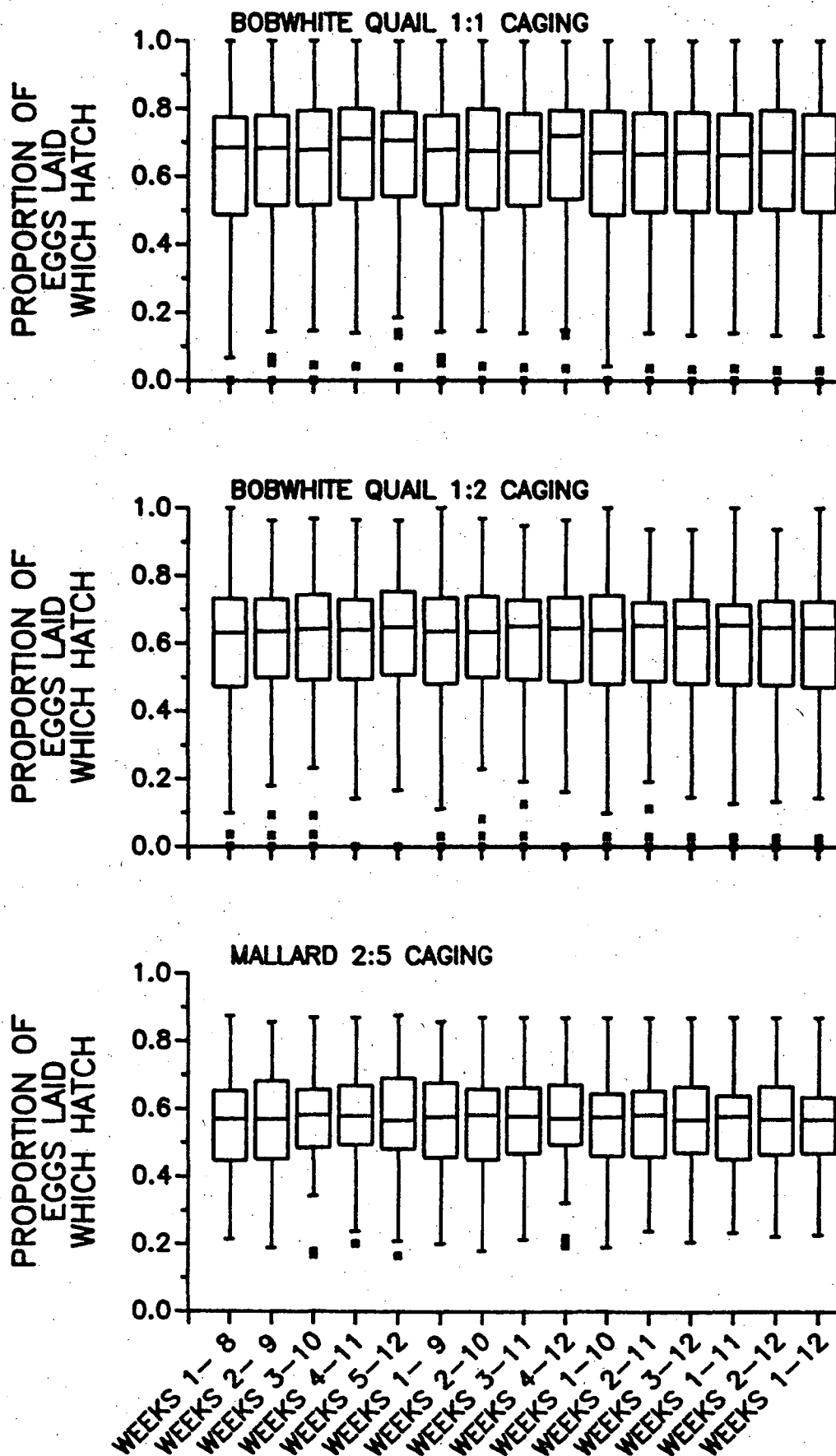
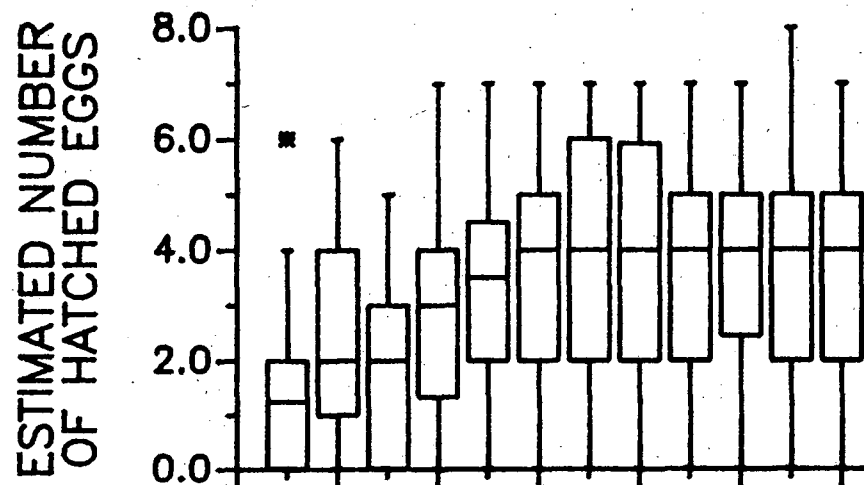
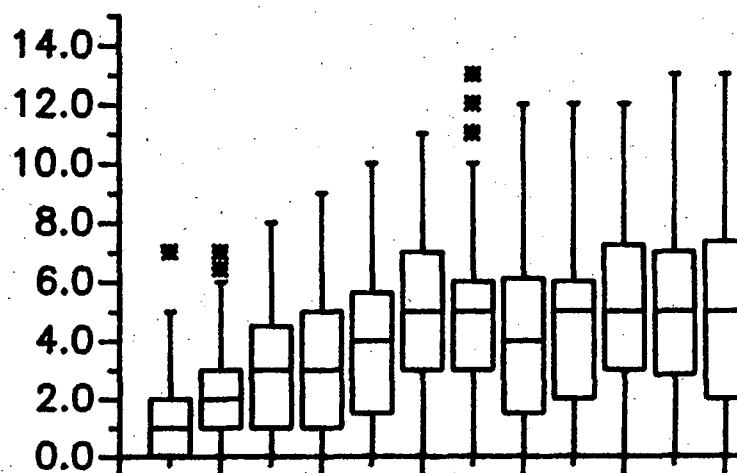


FIGURE 9: ESTIMATED NUMBER OF HATCHED EGGS

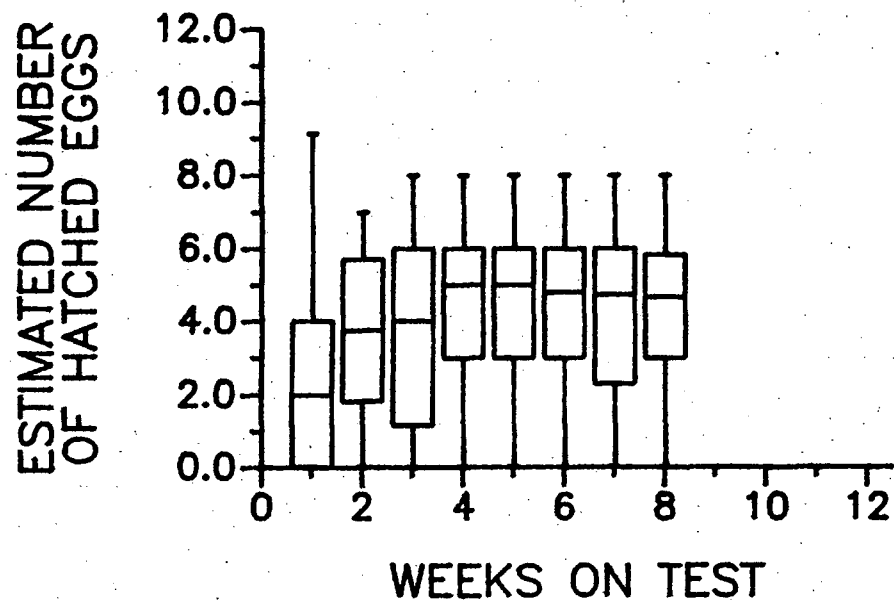
BOBWHITE QUAIL 1:1 CAGING



BOBWHITE QUAIL 1:2 CAGING



MALLARD 1:1 CAGING



MALLARD 2:5 CAGING

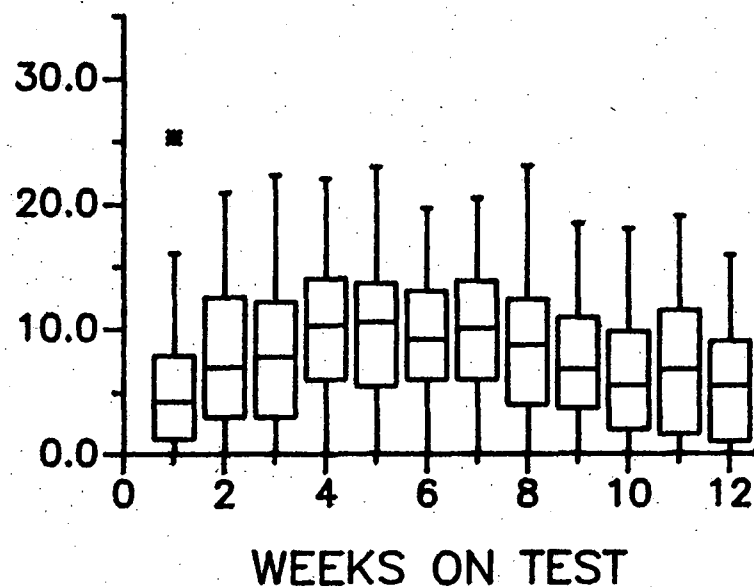


FIGURE 10: ESTIMATED HATCHED EGGS: TOTAL OVER  
SELECTED WEEKS

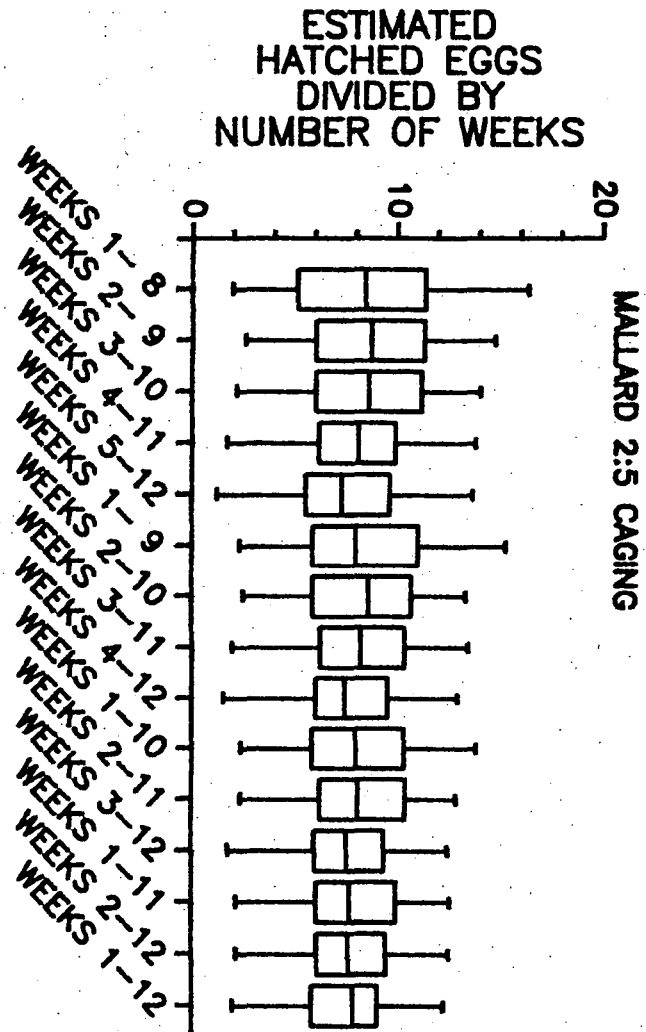
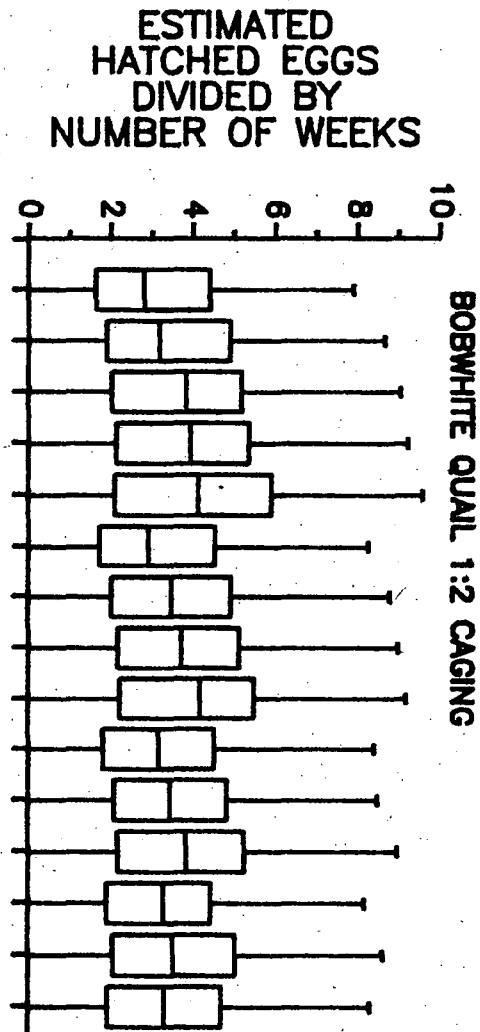
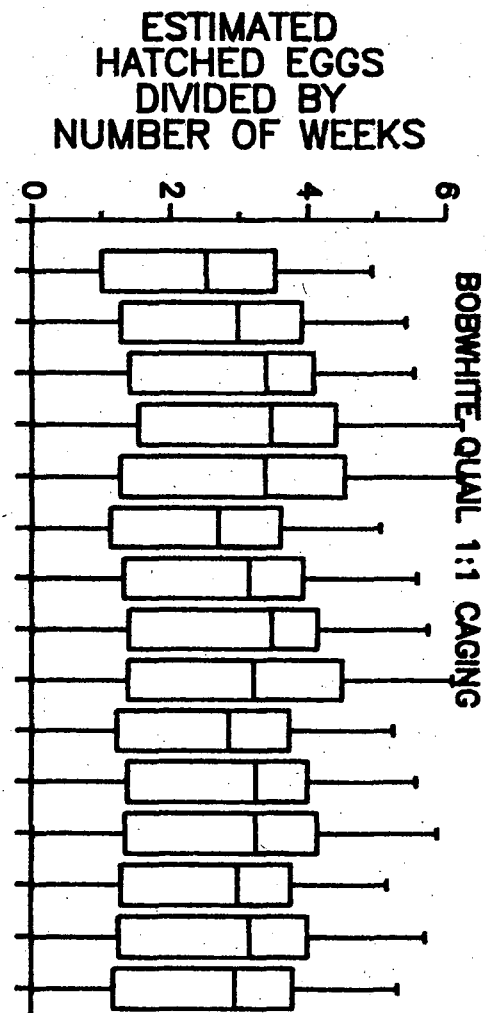


FIGURE 11: Q-Q PLOTS OF AMONG AND  
WITHIN EXPERIMENT RESIDUALS FOR  
BOBWHITE QUAIL 1:1 CAGING WEEKS 1-8

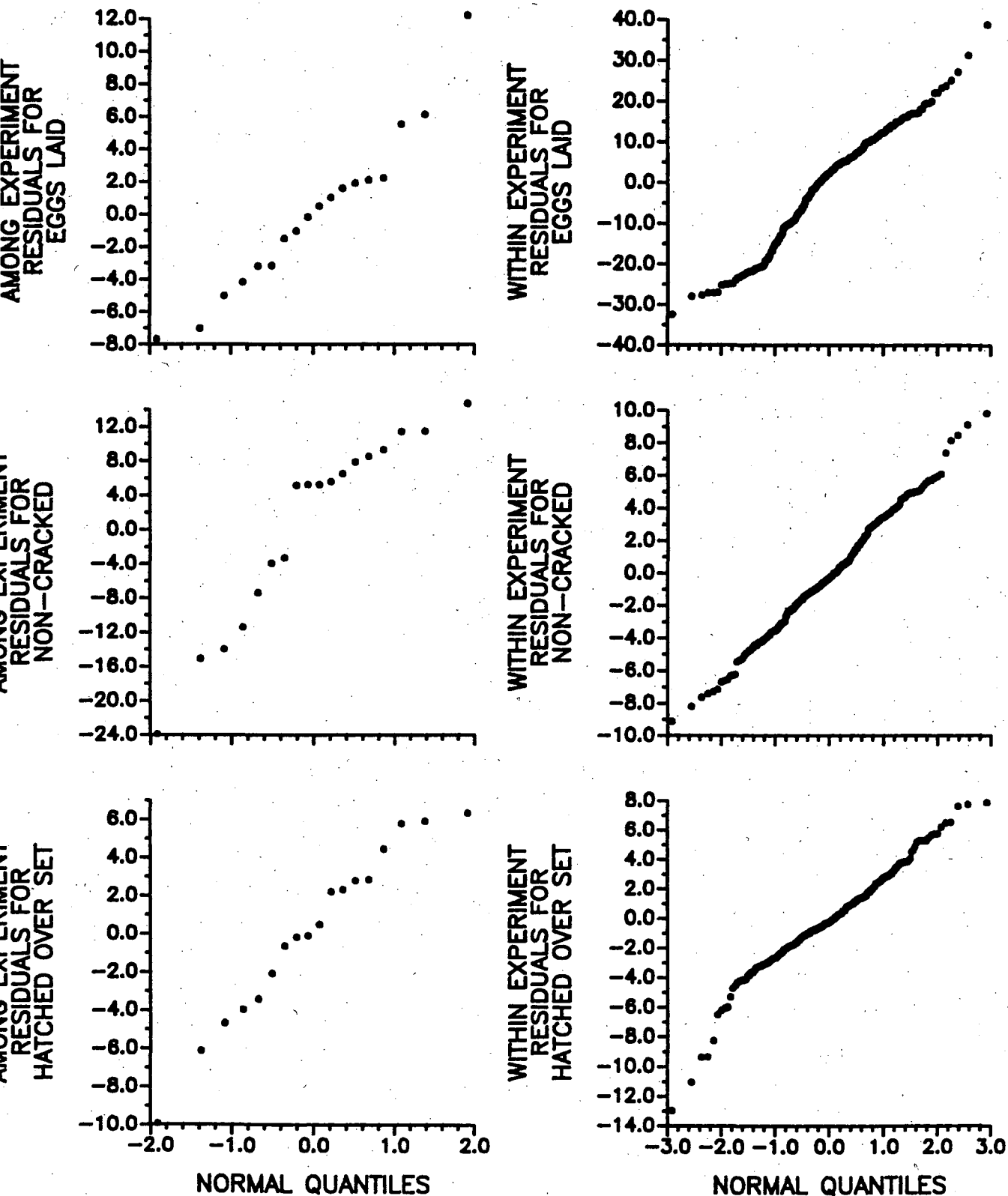


FIGURE 12: PAIRWISE SCATTERPLOTS FOR  
 AMONG EXPERIMENT PARAMETERS:  
 BOBWHITE QUAIL, 1:1 CAGING, WEEKS 1-8

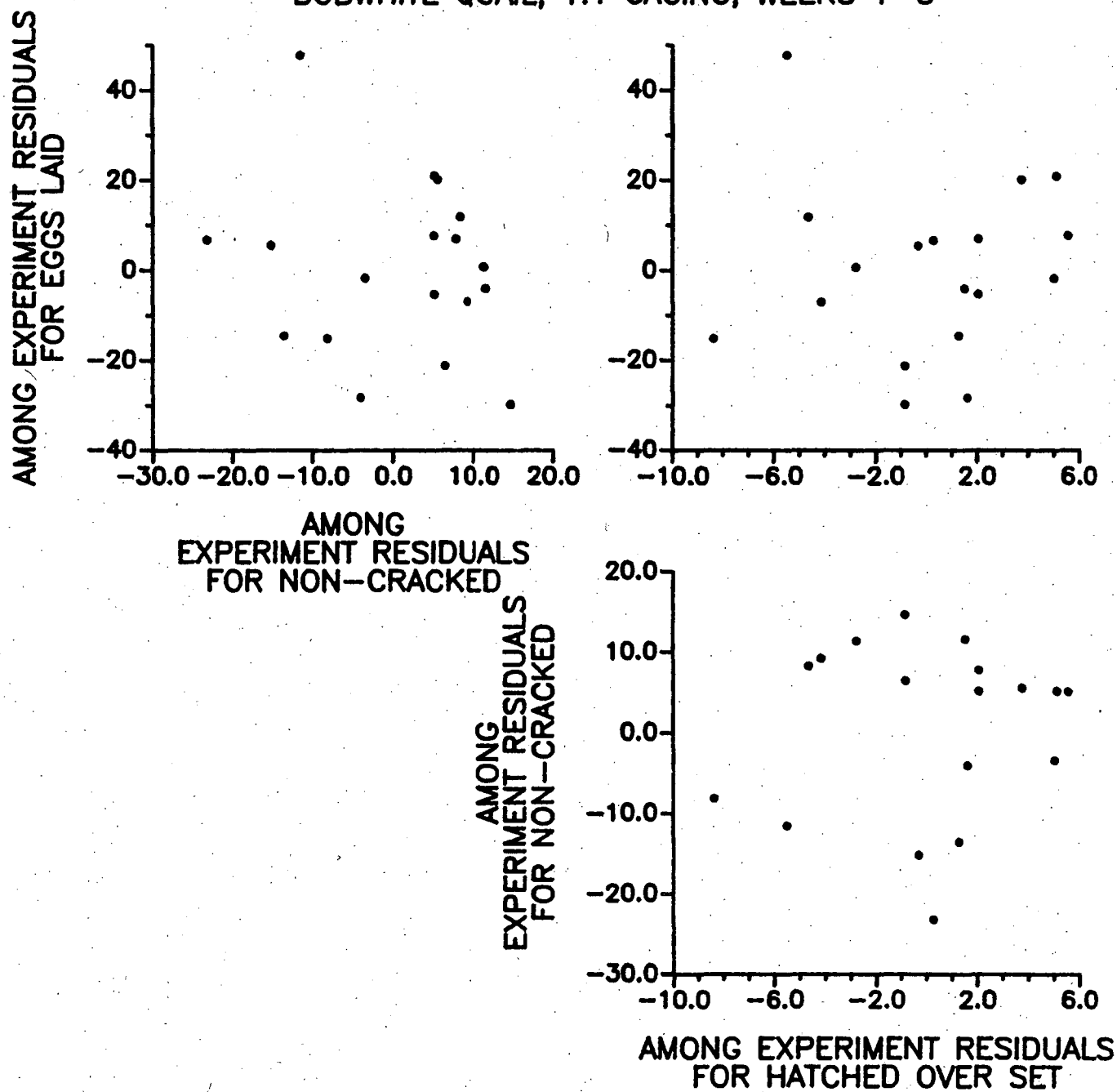
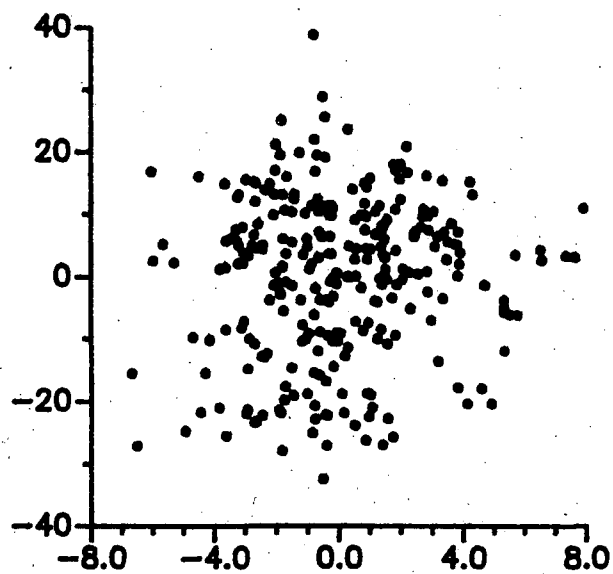
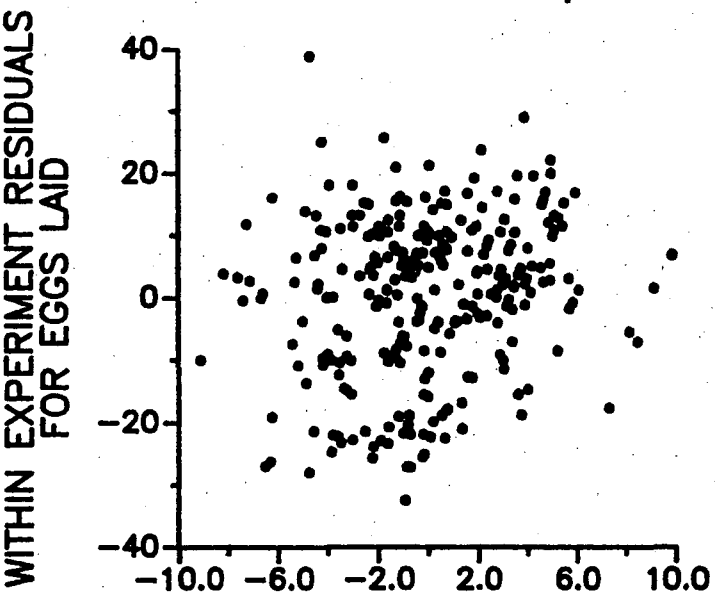
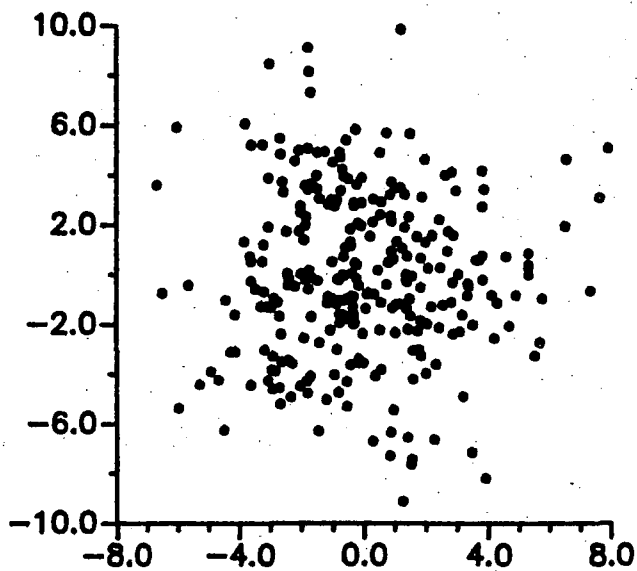


FIGURE 13: PAIRWISE SCATTERPLOTS FOR WITHIN  
EXPERIMENT PARAMETERS: BOBWHITE QUAIL,  
1:1 CAGING, WEEKS 1-8



WITHIN  
EXPERIMENT RESIDUALS  
FOR NON-CRACKED

WITHIN  
EXPERIMENT RESIDUALS  
FOR NON-CRACKED



WITHIN EXPERIMENT RESIDUALS  
FOR HATCHED OVER SET

FIGURE 14: Q-Q PLOTS OF AMONG AND  
WITHIN EXPERIMENT RESIDUALS FOR  
BOBWHITE QUAIL, 1:1 CAGING, WEEKS 1-12

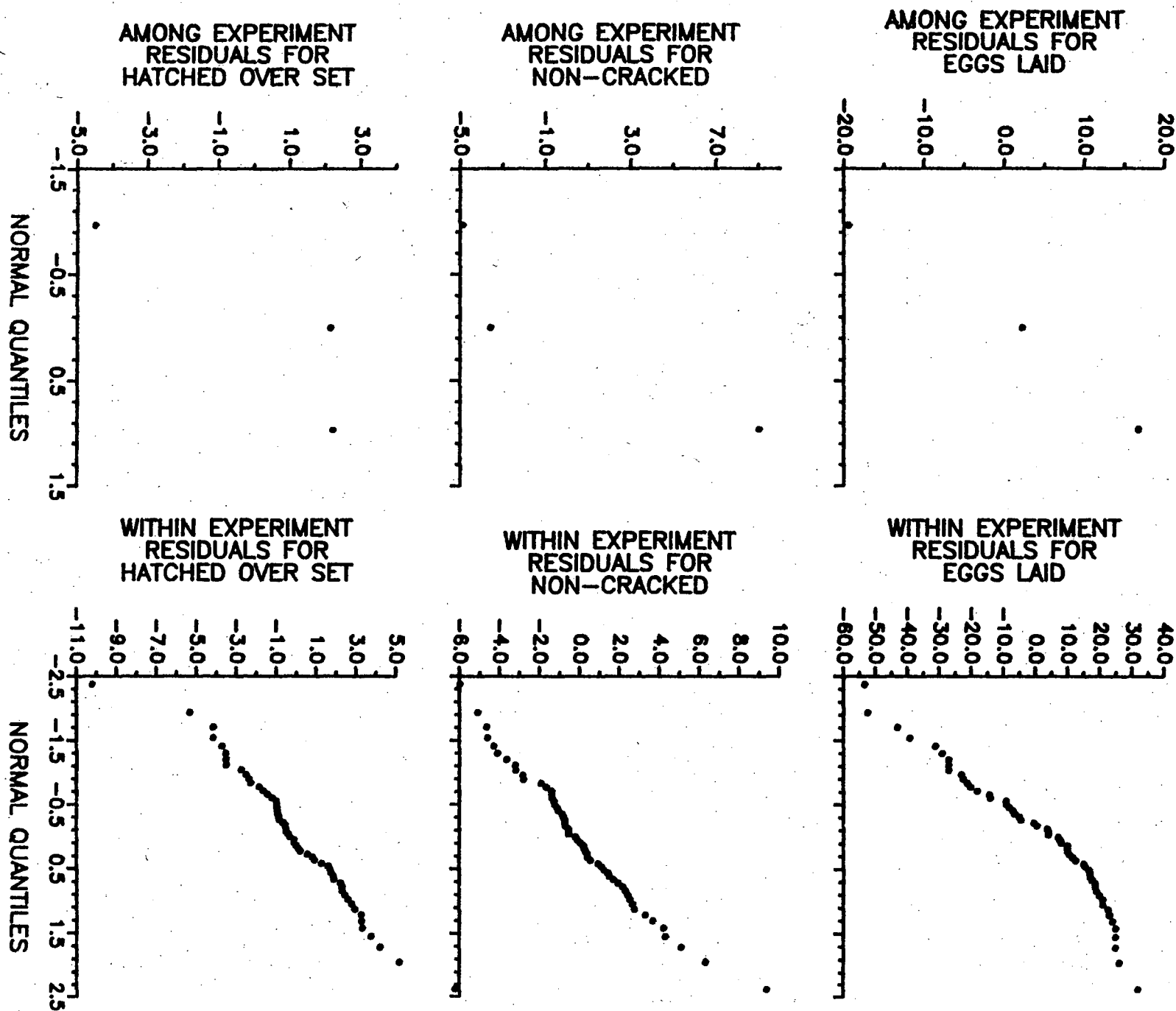


FIGURE 15: Q-Q PLOTS OF AMONG AND  
WITHIN EXPERIMENT RESIDUALS FOR  
BOBWHITE QUAIL, 1:1 CAGING, WEEKS 1-12  
(3 OUTLIERS DELETED)

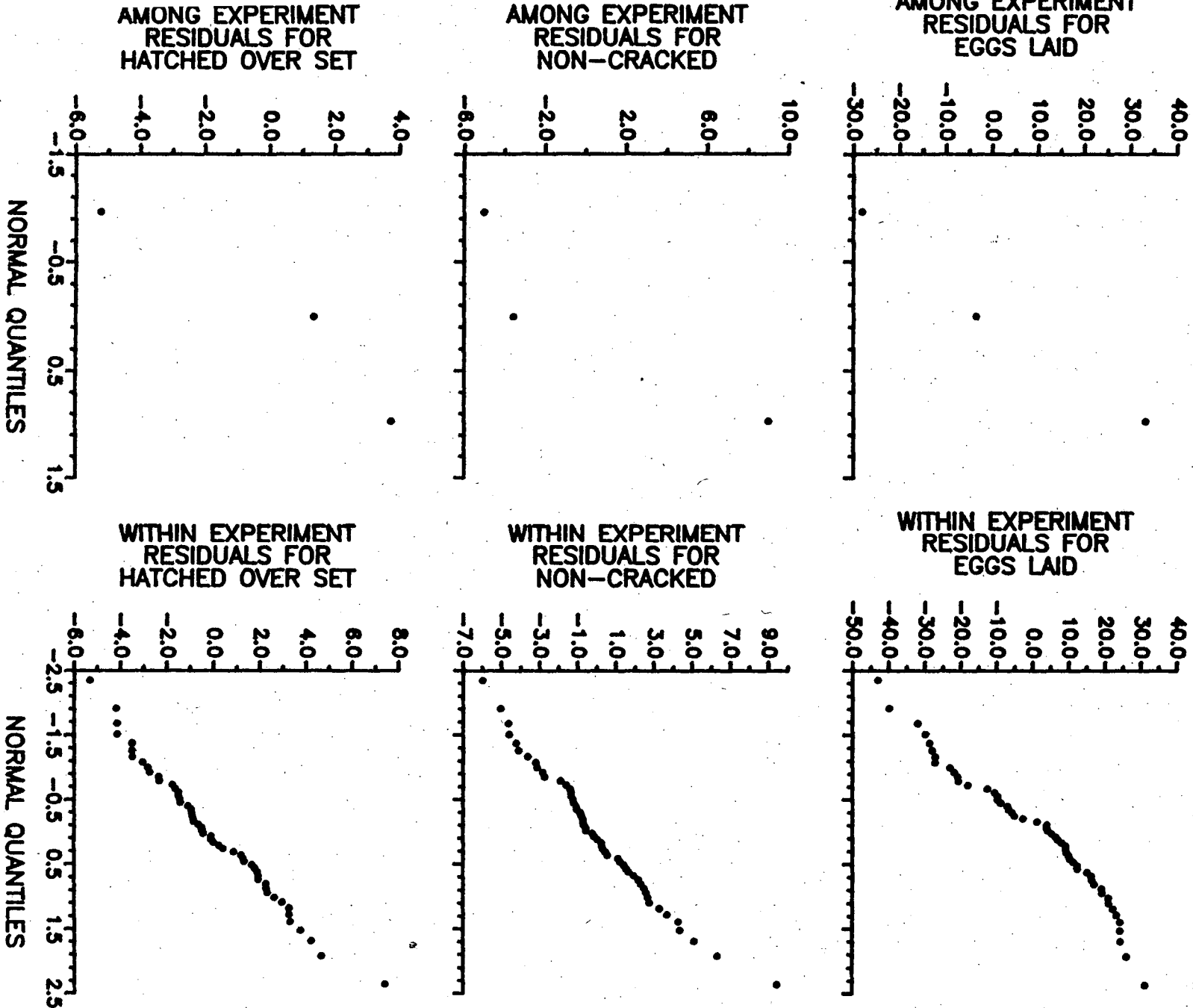


FIGURE 16: PAIRWISE SCATTERPLOTS FOR  
WITHIN EXPERIMENT RESIDUALS:  
BOBWHITE QUAIL, 1:1 CAGING, WEEKS 1-12

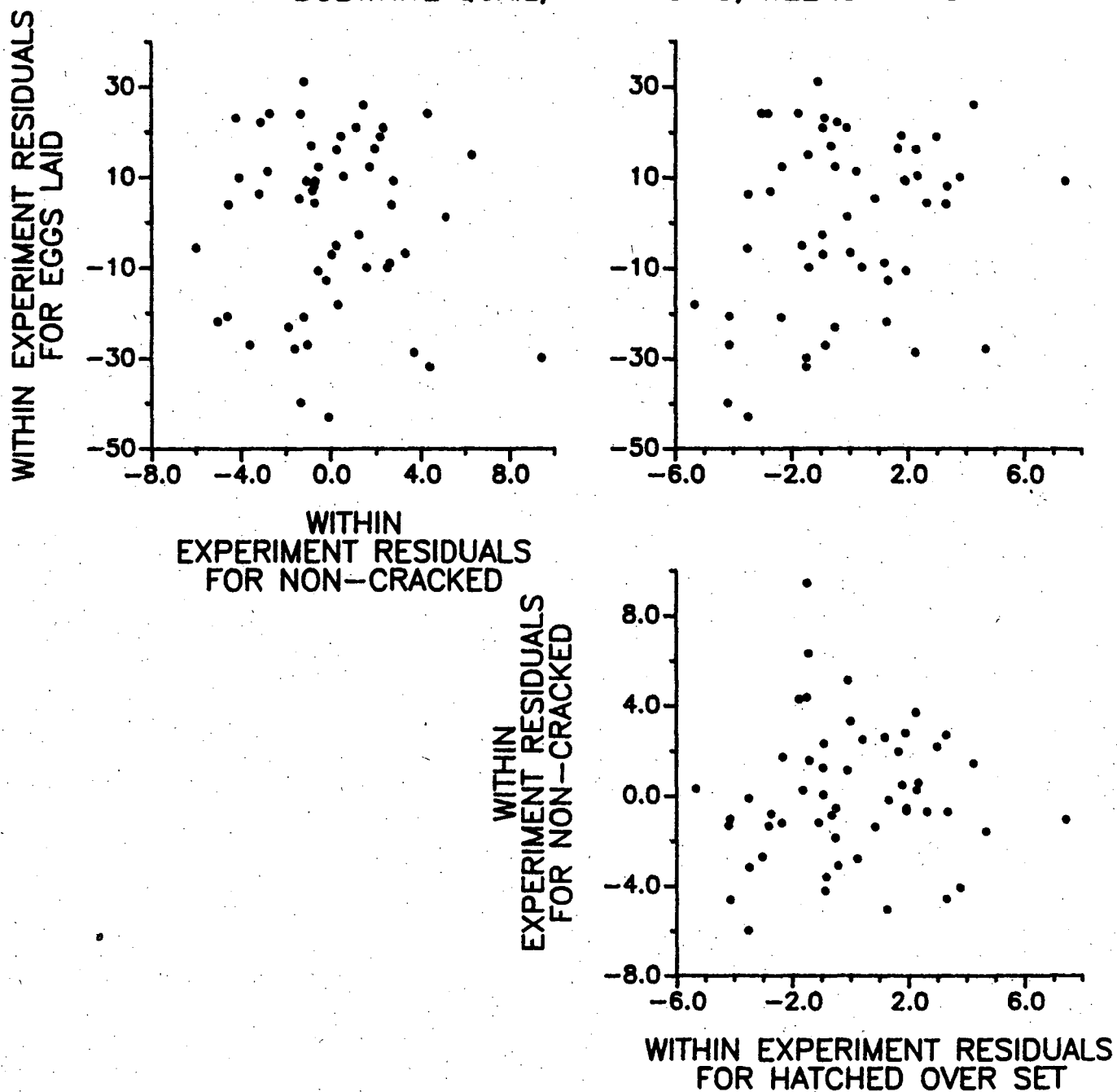


FIGURE 17: Q-Q PLOTS OF AMONG AND  
WITHIN EXPERIMENT RESIDUALS FOR  
BOBWHITE QUAIL, 1:2 CAGING, WEEKS 1-8

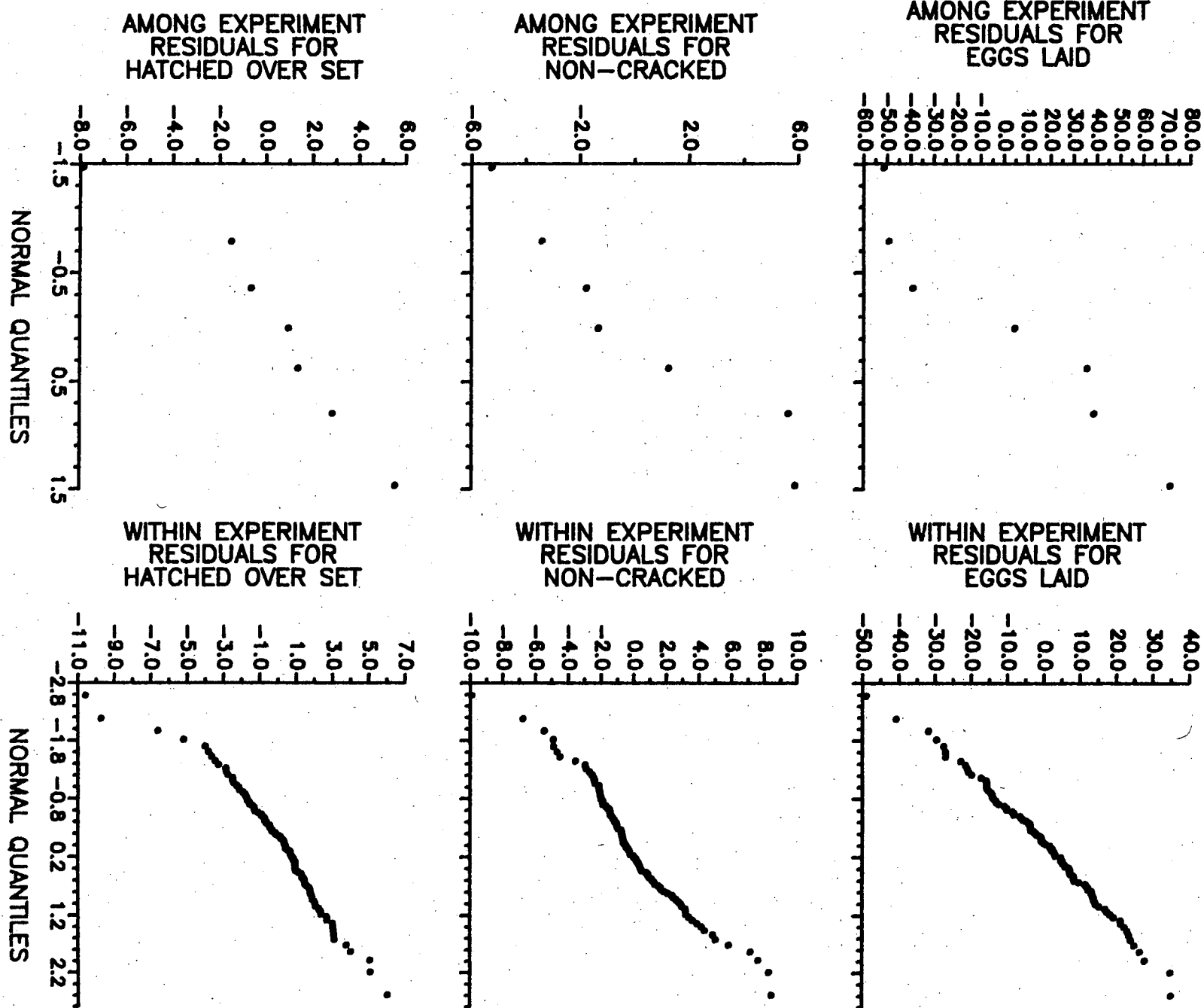


FIGURE 18: PAIRWISE SCATTERPLOTS FOR  
WITHIN EXPERIMENT RESIDUALS:  
BOBWHITE QUAIL, 1:2 CAGING, WEEKS 1-8

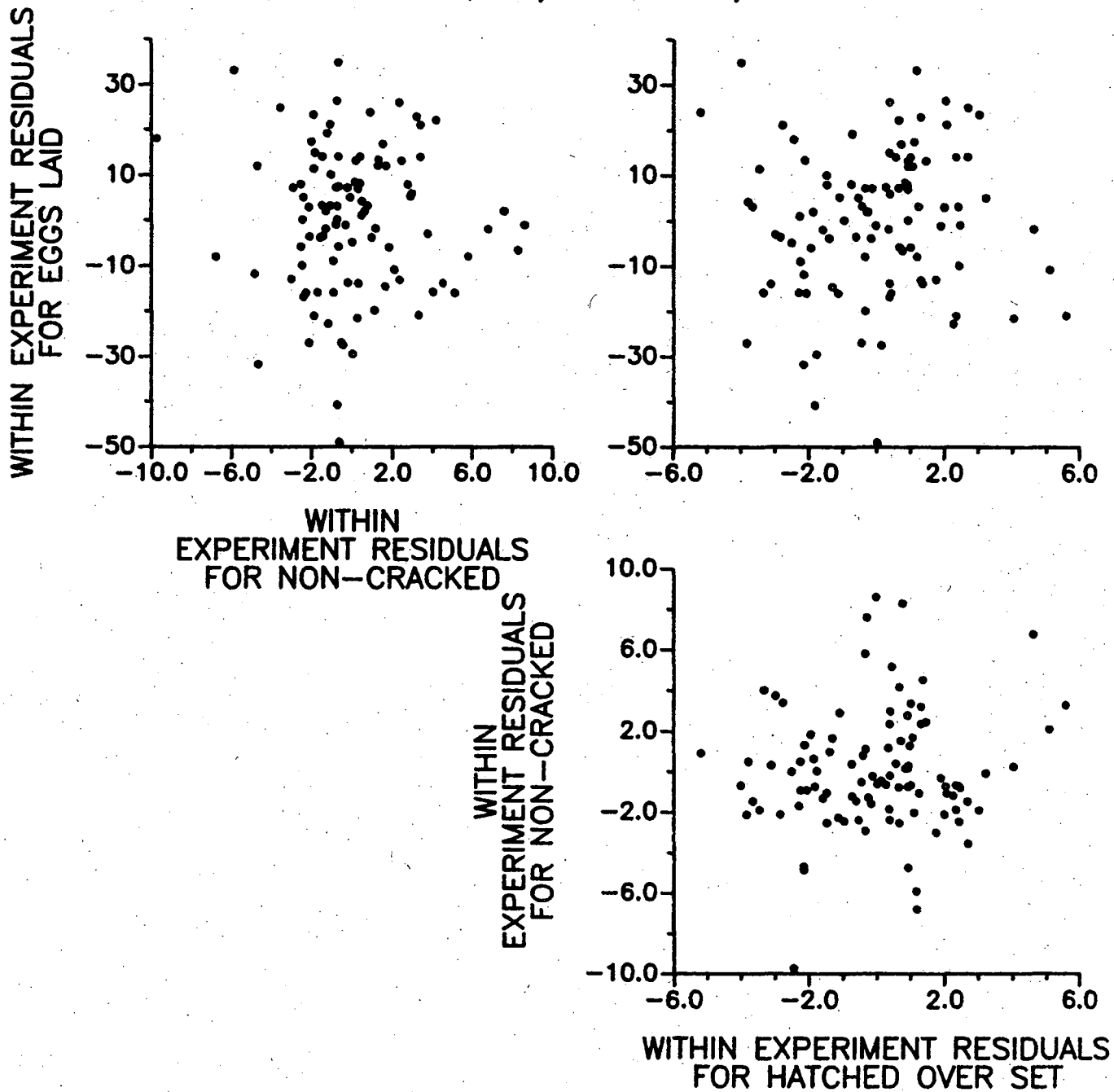


FIGURE 19: Q-Q PLOTS OF AMONG AND  
WITHIN EXPERIMENT RESIDUALS FOR  
BOBWHITE QUAL, 1:2 CAGING, WEEKS 1-12

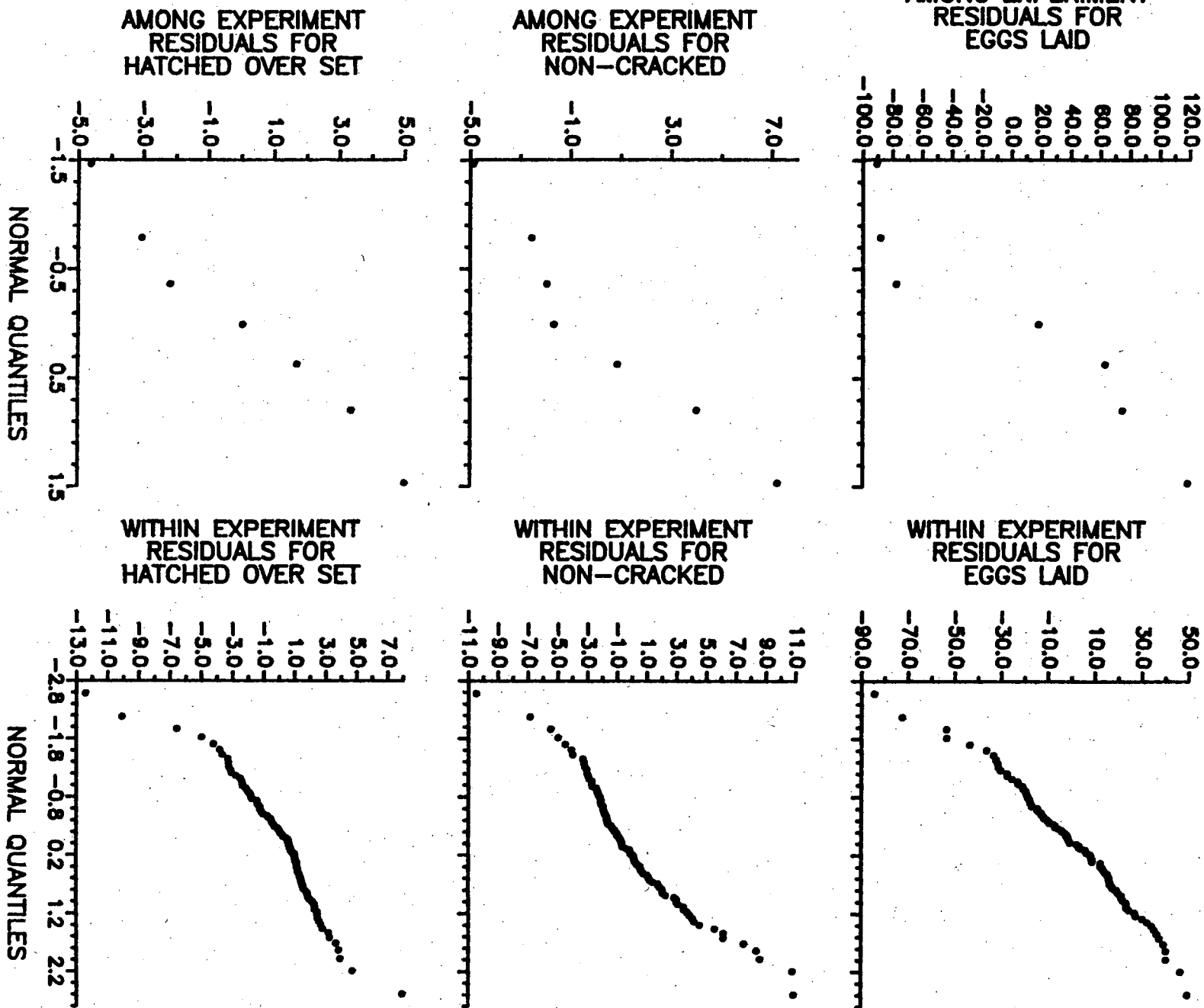


FIGURE 20: PAIRWISE SCATTERPLOTS FOR  
WITHIN EXPERIMENT RESIDUALS:  
BOBWHITE QUAIL, 1:2 CAGING, WEEKS 1-12

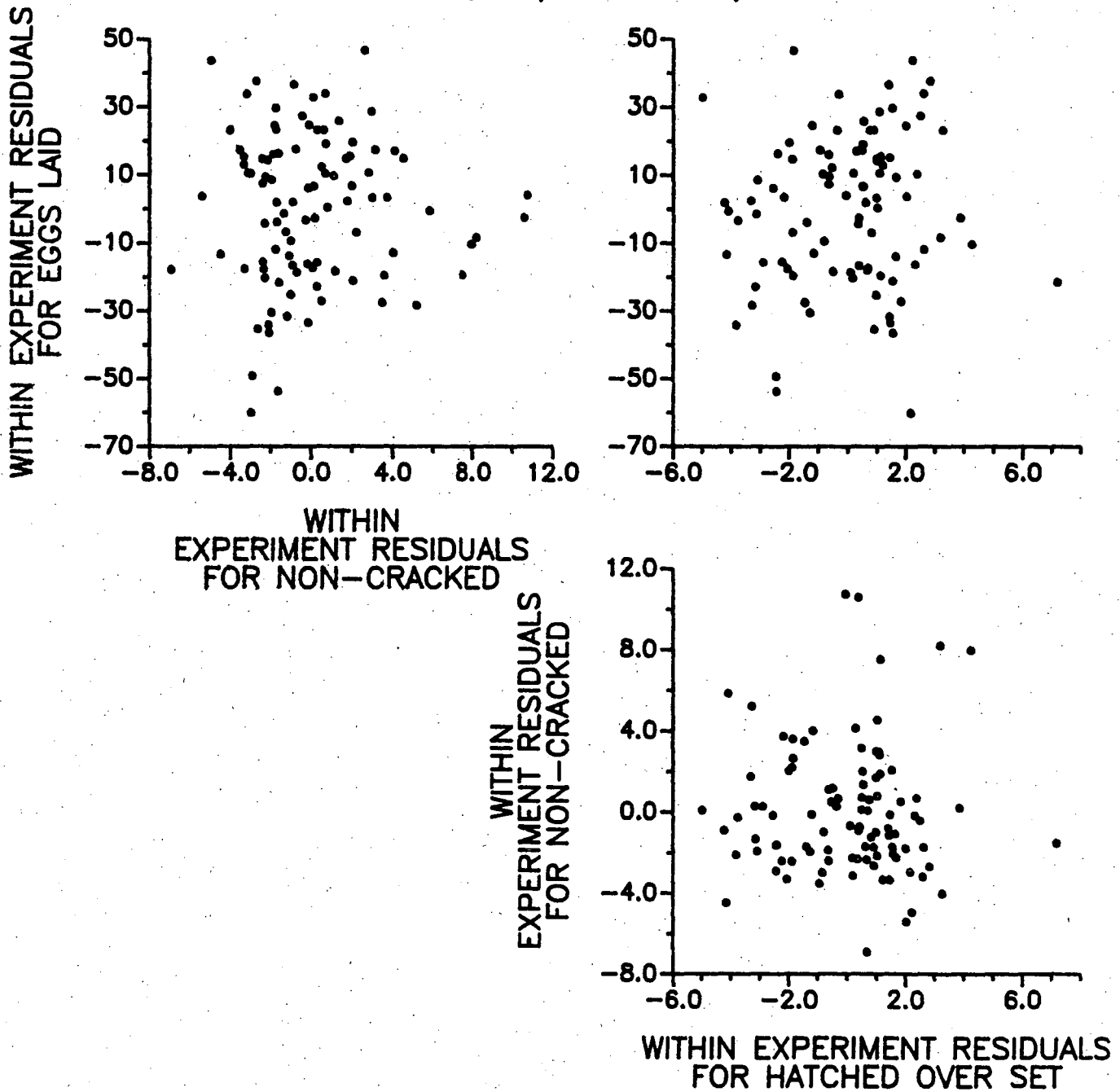


FIGURE 21: Q-Q PLOTS OF AMONG  
AND WITHIN EXPERIMENT RESIDUALS FOR  
MALLARD, 1:1 CAGING, WEEKS 1-8

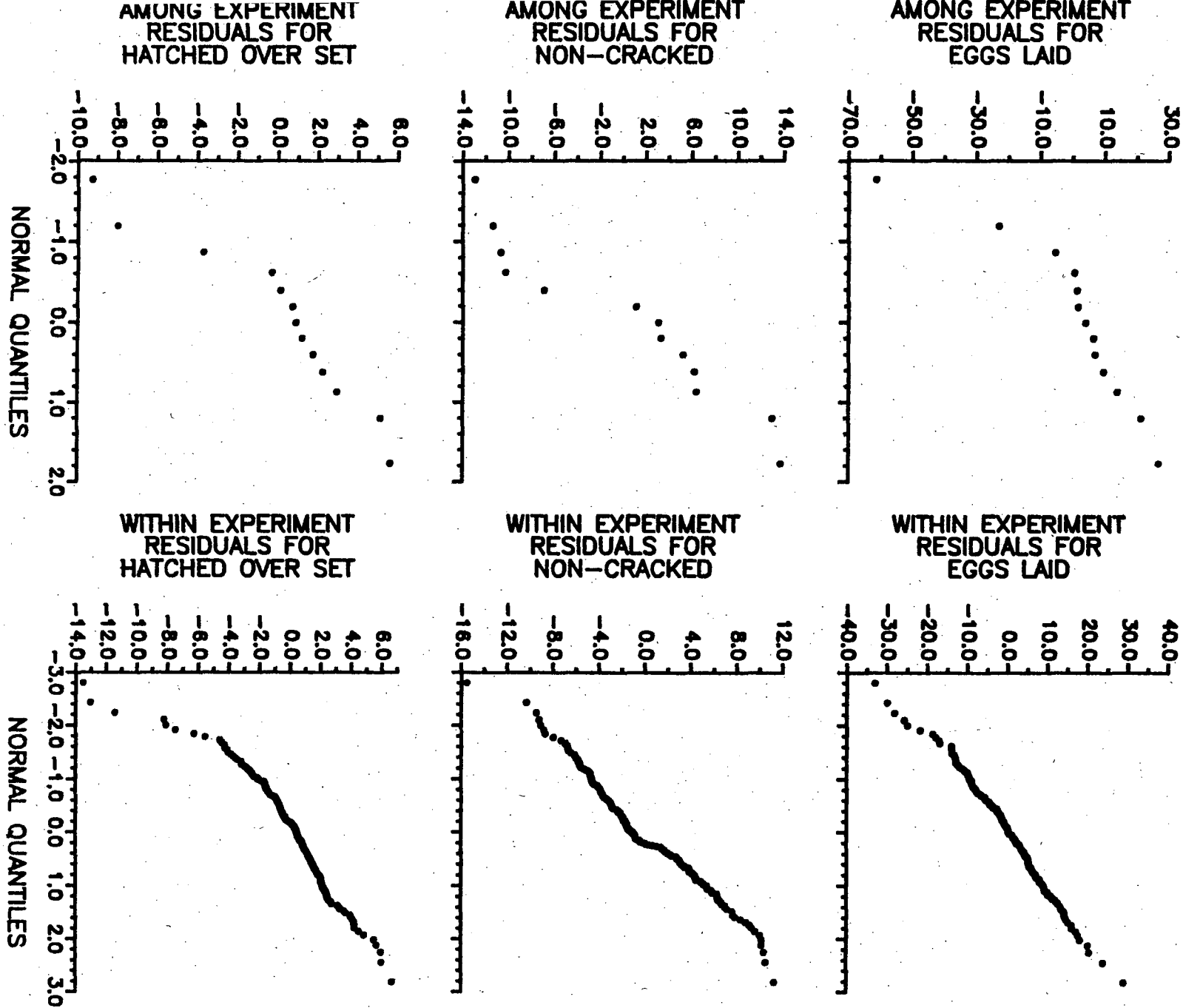


FIGURE 22: PAIRWISE SCATTERPLOTS FOR  
WITHIN EXPERIMENT RESIDUALS:  
MALLARD, 1:1 CAGING, WEEKS 1-8

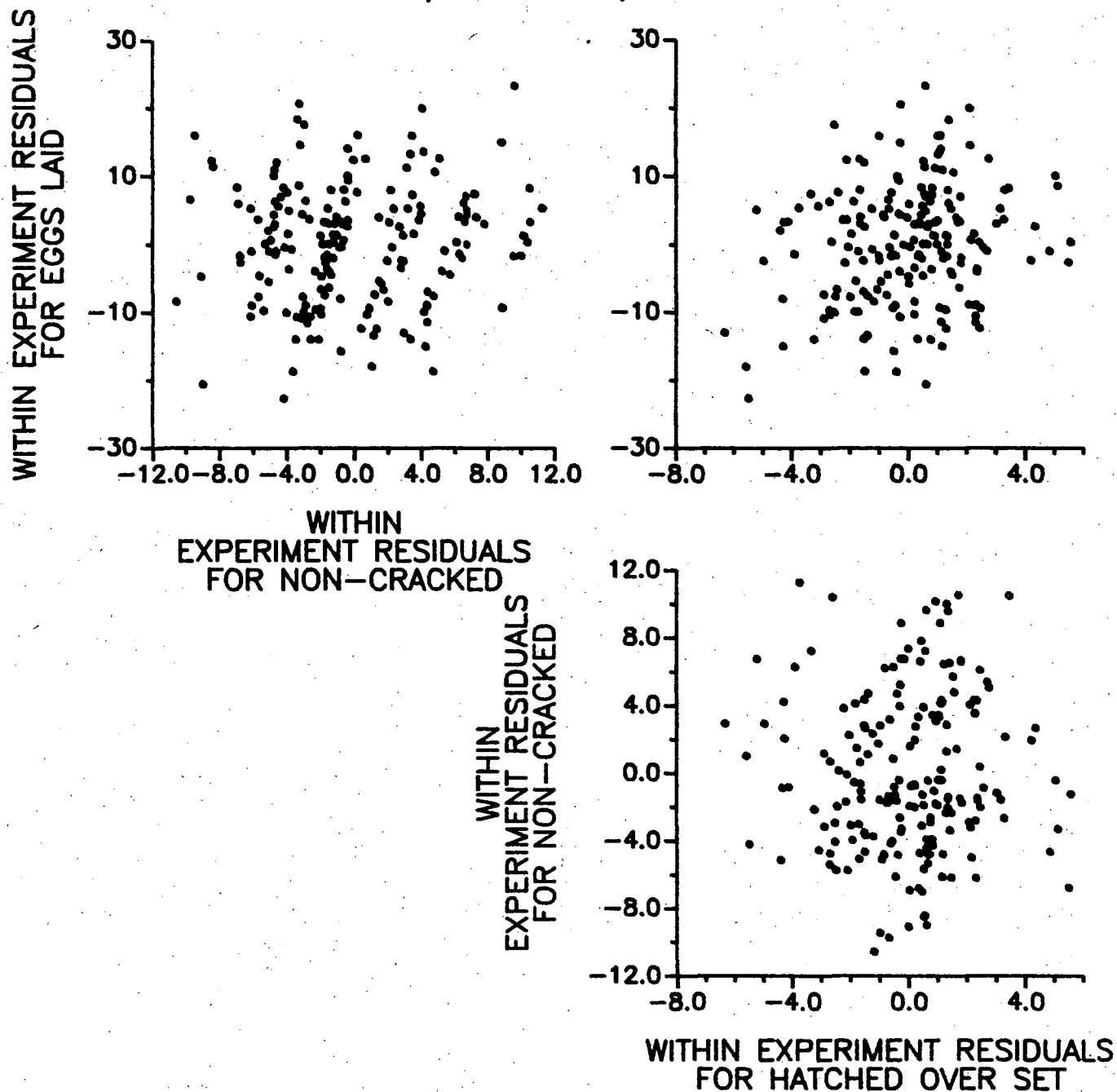


FIGURE 23: Q-Q PLOTS OF AMONG AND WITHIN EXPERIMENT RESIDUALS FOR MALLARD, 2:5 CAGING, WEEKS 1-8

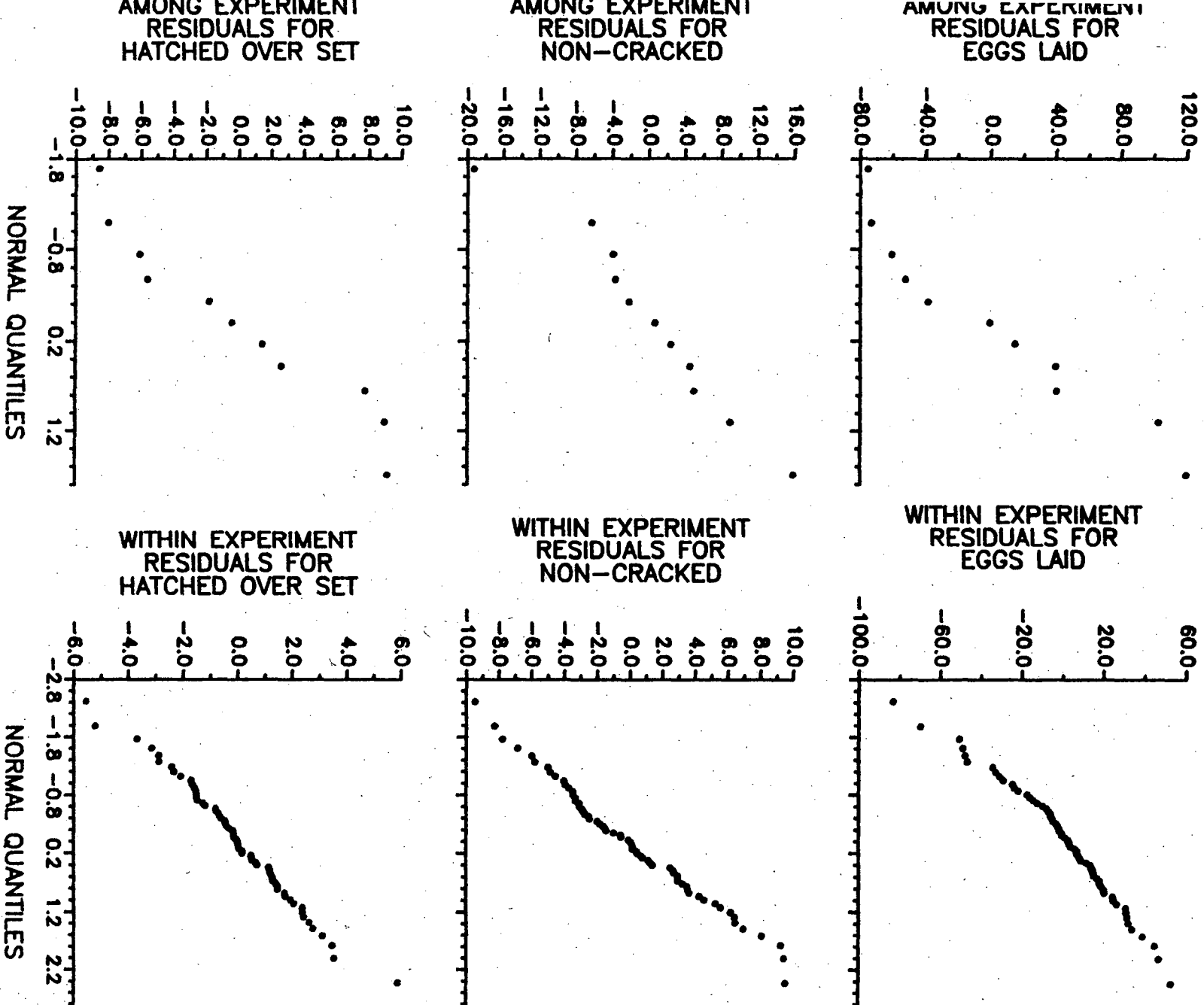


FIGURE 24: PAIRWISE SCATTERPLOTS FOR  
WITHIN EXPERIMENT RESIDUALS:  
MALLARD, 2:5 CAGING, WEEKS 1-8

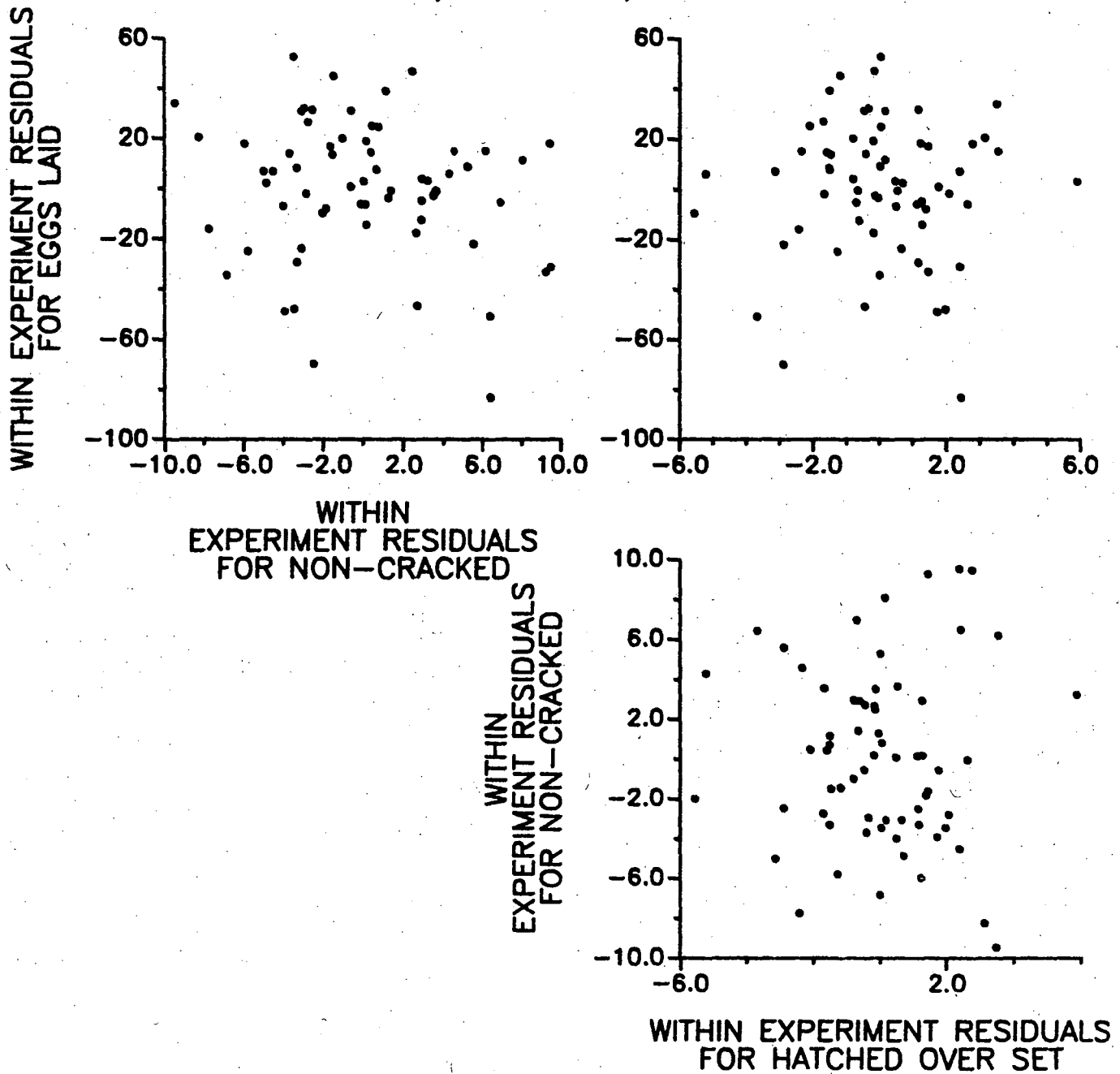


FIGURE 25: Q-Q PLOTS OF AMONG AND  
WITHIN EXPERIMENT RESIDUALS FOR  
MALLARD, 2:5 CAGING, WEEKS 1-12

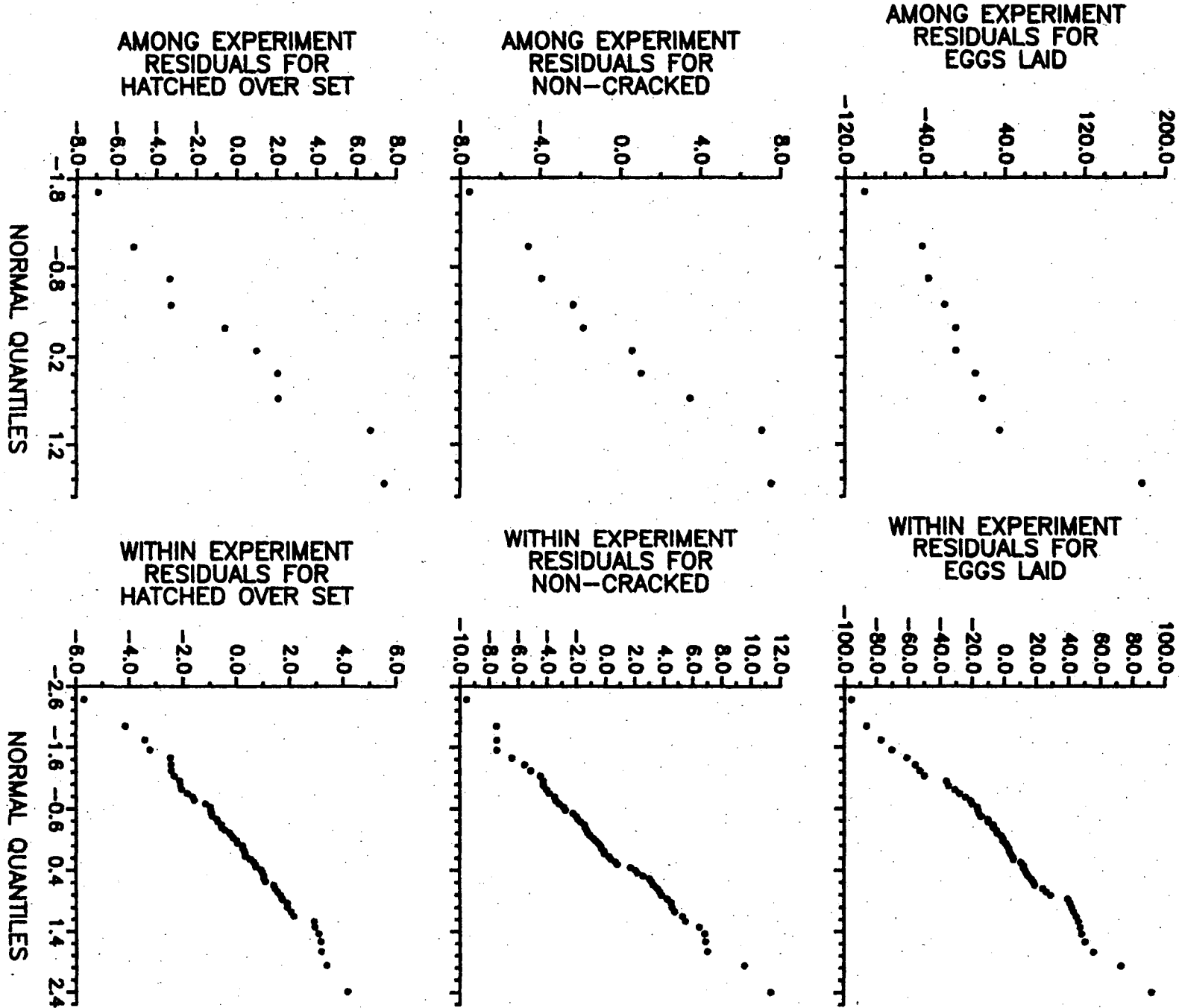
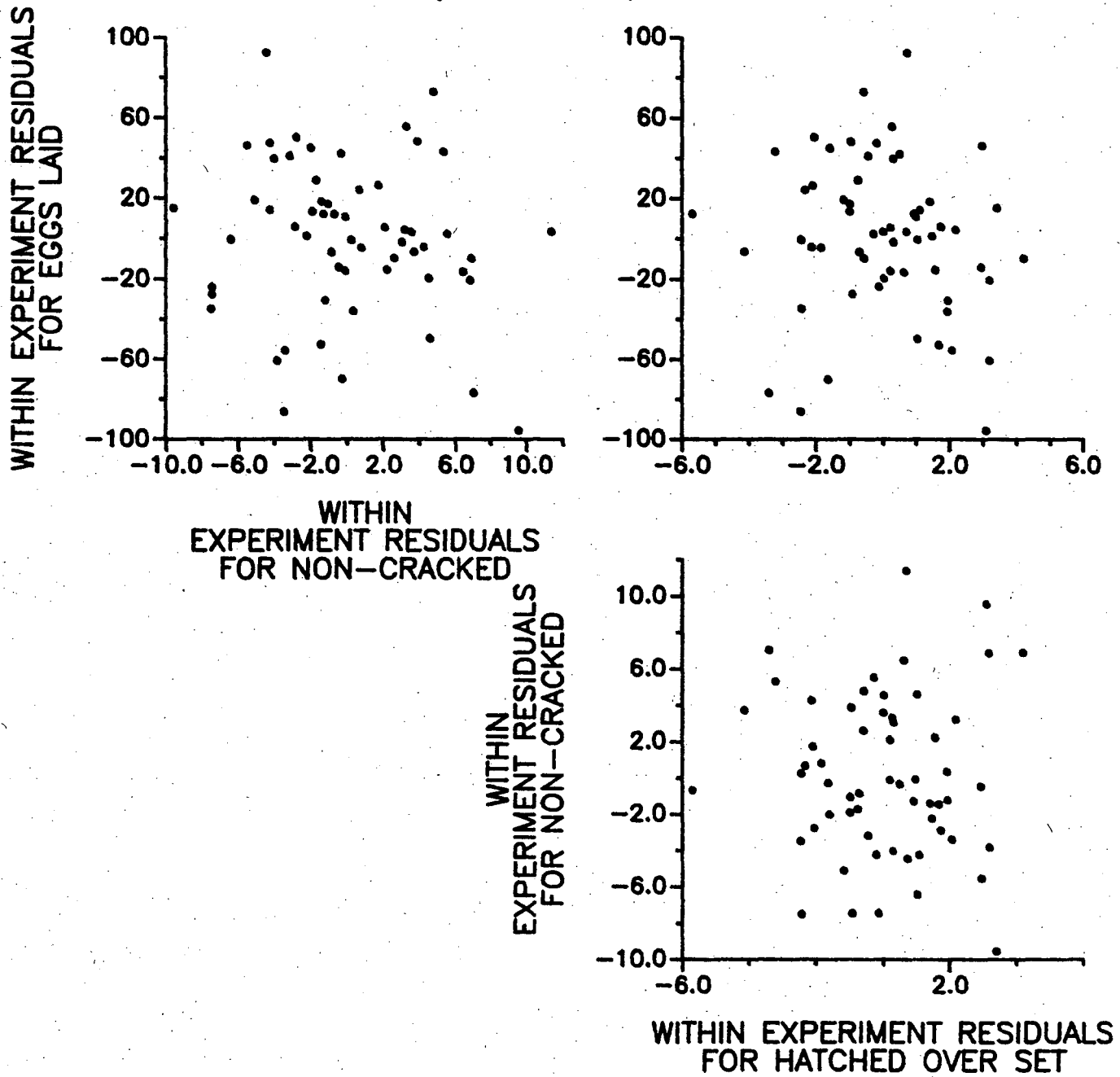


FIGURE 26: PAIRWISE SCATTERPLOTS FOR  
WITHIN EXPERIMENT RESIDUALS:  
MALLARD, 2:5 CAGING, WEEKS 1-12



## **PART B: STATISTICAL POWER ANALYSIS**

## 1) INTRODUCTION

The avian reproduction (AR) test is one of a battery of tests required before the registration of a chemical such as a pesticide. The test is required when it is believed that use of the chemical will result in wild birds being exposed to levels which could adversely affect their reproduction. The protocol for these studies is based upon guidelines prepared by USEPA (McLane, 1986). The guidelines describe experiment conditions such as species, environment, test standards, number of test animals and variables to be collected. The test protocols are left open in many aspects. This is done to allow individual laboratories to adapt the protocol to their particular situation but has lead to some difficulties in comparing the results of different studies which may use different statistical tests (Mineau *et al.*, 1994).

A brief description of the AR test follows. A set of male and female birds are placed in each pen. The number of males and females in a pen varies with the species and the design chosen by the laboratory. The cages are randomly divided among at least 3 treatment groups. One of the treatment groups is a control and the rest have graded dietary levels of the test chemical. The number of cages is the same for all treatment groups. During an acclimatization period the test chemical is introduced into the diet and the photoperiod for the cages is set to maintain the birds in reproductive quiescence. At the end of the acclimatization period the photoperiod is changed to induce egg-laying. Eggs are removed from the pen each day and checked for cracks. A few non-cracked eggs are removed for eggshell thickness measurement. The remaining eggs are placed ('set') in the incubator. The state of the eggs is monitored and the number which hatch and the number of chicks which survive to 14 days is recorded. The avian reproduction study involves the recording of many variables but this analysis will focus on three variables of primary interest: number of eggs laid, proportion of eggs laid which are non-cracked and proportion of eggs set which hatch.

The AR test is run on two different species: Bobwhite quail and Mallard duck. Each species can be run using either of two different caging protocols: Bobwhite quail can be run using 1:1 (male:female) or 1:2 caging while Mallard studies can use 1:1 or 2:5 caging. The recommended minimum number of cages to be used in an AR study is shown in Table 1. This sample size was selected to provide a power of 0.8 that a 20% reduction in reproductive activity would be detected. Note that although 1:1 caging was accepted by the USEPA there was little data available on the 1:1 studies and hence the sample size requirements were not made explicit but a reference was made to Walpole and Myers (1972) for sample size calculations. The actual sample sizes used in 49 AR tests are also shown in Table 1. There are a wide variety of sample sizes used but none of the 1:1 studies attain the suggested 25 cages.

The protocol requires that birds be kept on test for a minimum of 10 weeks. The test periods for 49 AR studies are shown in Table 2. Test periods of 8 or 9 weeks are common with 1:1 caging studies but birds have been kept on test for as long as 13 weeks.

The sample size requirements were based on F-tests comparing several treatment groups (Walpole and Myers, 1972). The protocol recommends using an arcsine transformation followed by an analysis of variance or a contingency table analysis for the discrete data. However, in the analysis of actual experiments several alternate methods of analysis have been used. Test procedures used include ANOVA, t-tests, contingency table analyses, linear logistic models and Kruskal-Wallis procedures. The data are sometimes transformed prior to analysis using the angular transformation (arcsine square-root), modified angular (Chanter, 1975) or log transformation. The number of eggs laid is sometimes transformed to a proportion by dividing by the theoretical maximum number of eggs (1/day/hen) or the observed maximum. Some studies use Cochran's procedure (Cochran, 1943) to weight the observations. The comparison of the analysis of different experiments is further complicated by the use of several different multiple comparison procedures such as Scheffe's, Duncan's, Dunnett's, William's and Bonferroni. The power of the design under these alternate transformations, weightings and test procedures is unknown.

The objective of the analysis described here is to examine the power of various alternative procedures for the analysis of AR studies and to make recommendations on the sample size required to attain the goals set out in the USEPA guidelines. A review of statistical techniques for other variables is given by MacLeod (1994).

## 2) DISTRIBUTION OF CONTROL DATA

The control data by week from 49 AR studies was available to provide estimates of the parameters of the distribution. The model fitting is outlined below but is described in more detail in part A of this report. The model fitted to the control data was used as a basis for generating observations for the simulation study.

The shortest duration of weeks on test used in these trials was 8 and the longest was 13 but it was used only twice. It was decided to examine two extremes of duration of 8 and 12 weeks. The number of observations available for each species caging and test duration examined is shown in Table 3. There was no data available for Mallards in 1:1 caging for 12 weeks on test. Whenever an experiment lasted longer than 8 weeks the first 8 weeks on test were used to fit the distribution of experiments of 8 weeks duration since the individual weeks results were available. Thus experiments which lasted 12 weeks provide information for

both durations.

The control data were fitted to a weighted MANOVA separately for each species caging and duration. The model was fitted to the 3 variables: number of eggs laid (LAID), the proportion eggs laid which were non-cracked (NC/LA) and the proportion of eggs set which hatch (HA/SE). For some pens the number of eggs laid or the number of non-cracked eggs was zero. The proportion of time this occurred was noted. The two proportion variables were transformed using a logit transformation with an adjustment for observations at 0 or 1

$$y = \ln(g/(1-g))$$

$$\begin{aligned} \text{where } g &= 1/4n \quad \text{if } p=0.0 \\ &= p \quad \text{if } 0.0 < p < 1.0 \\ &= 1-1/4n \quad \text{if } p=1.0 \end{aligned}$$

where  $p$  is the observed probability and  $n$  the denominator used in calculating the probability. This transformation was chosen because it provided a good fit to the observed data (Part A; MacLeod, 1994).

The proportion variables were also weighted using

$$w = \text{SQRT} \left[ \left[ (n-1) \rho + 1 \right] / n \right]$$

where  $\rho$  is the intrapen correlation for the proportion. This weighting is equivalent to the weighting scheme for percentages proposed by Cochran (1943).

A weighted MANOVA with the weighting term different for each variable was then fitted separately to each design. For each design a normal probability plot of the residuals for each variable was made and in addition a scatterplot matrix of the residuals was made. Some observations appeared to be outliers. These observations were set aside and the MANOVA was redone.

The parameters fitted to the MANOVA are given in Tables 4 and 5 for bobwhite quail and mallard respectively. The proportion and mean values of outliers shown in the table includes those instances when the number of eggs laid or the number set were 0 as well as the outliers detected using the probability plots.

### 3) SIMULATION MODEL

#### 3.1) Patterns of treatment effect

A simulation was run to determine the proportion of time a statistical test would detect a given dose to be significant given a certain level of the treatment effect. It was assumed that the treatment only affected the mean value for the distribution. The intrapen correlations, the variance covariance matrix, the proportion of outliers and the distribution of outliers were assumed to be unaffected by the treatment.

The treatment effects studied were defined as follows. The simulation was restricted to experiments with a control and 3 graded levels of the test compound. Let  $\delta_{ki}$  denote the mean value for variable  $k$  treatment  $i$  where  $i=1,2,3,4$  denotes the control, low, medium and high dose groups respectively. The vector of mean values is

$$\underline{Y}_k = (\delta_{k1}, \delta_{k2}, \delta_{k3}, \delta_{k4})$$

The objective of the study is to detect at what dose the mean value declines to a given fraction ( $f_k$ ) of the control value. Eight possible patterns for the treatment mean were examined. The first pattern is one with no treatment effect. This is used to assess the significance level of the tests. Six patterns have various thresholds below which the treatment dose not affect the response and above which there was a linear decline. The decline will be at a rate which gives a value of  $f_k \delta_{k1}$  at one of the three treatment doses. The eighth pattern involves the dose declining to the required fraction at the low dose and then remaining constant for higher doses. (This pattern had been seen in some data sets and the dose response curve may have this shape due to a rate limited uptake of the chemical.) The eight possible patterns for  $\underline{Y}_k$  are

$$g(1)' = (1, 1, 1, 1) \delta_{k1}$$

$$g(2)' = (1, 1, 1, f_k) \delta_{k1}$$

$$g(3)' = (1, 1, (1+f_k)/2, f_k) \delta_{k1}$$

$$g(4)' = (1, (2+f_k)/3, (1+2f_k)/3, f_k) \delta_{k1}$$

$$g(5)' = (1, 1, f_k, 2f_k) \delta_{k1}$$

$$g(6)' = (1, (1+f_k)/2, f_k, (3f_k-1)/2) \delta_{k1}$$

$$g(7)' = (1, f_k, 2f_k-1, 3f_k-2) \delta_{k1}$$

$$g(8)' = (1, f_k, f_k, f_k) \delta_{k1}$$

The 8 treatment patterns are shown in Figure 1. The horizontal dashed line shows

the magnitude of the treatment which is required to be detected. The vertical dashed line show the lowest dose at which the required effect occurs. For  $g(2)$ ,  $g(3)$  and  $g(4)$  the treatment attains the required effect at the highest dose level. For  $g(5)$  and  $g(6)$  the required effect occurs at the middle dose while for  $g(7)$  and  $g(8)$  the required effect is present at the lowest dose.

The required treatment effects are expressed as a proportion of the control means. The mean value for the control, however, can't be expressed in closed form. The simulation program calculated the mean value for the control using a numerical integration. The required mean for the treatment could then be calculated and the distribution mean which would give the required treatment mean was then derived using a reverse numerical integration.

The simulation study was designed to determine the sample size required to detect a treatment which caused a decline to a fraction  $f$  of the control level. The dose which attained this decline varied among the treatment patterns. For patterns 2, 3 and 4 the required decline occurred for the high dose, while for patterns 5 and 6 it occurred at the medium dose and for patterns 7 and 8 it occurred at the low dose. Thus although treatment patterns 4, 6 and 7 differ only in the scale of the slope they differ in the dose at which the treatment causes the required decline.

### 3.2) Data generation

The data were generated using the trivariate normal distribution fitted to the control data (Part A). Except that the mean for each treatment group was set to the value which gave the required treatment effect for the pattern being studied.

The first variable was converted to eggs laid through rounding to an integer. The second variable was converted to number of non-cracked eggs through inverting the logit transformation, multiplying by the number of eggs laid, and rounding to an integer. The number of eggs set was then derived as the number of non-cracked eggs minus the number removed. The number of eggs removed was set at 1 egg per pen every other week or 4 eggs for experiments lasting 8 weeks and 6 eggs for experiments lasting 12 weeks. The third variable was converted to number of eggs which hatch through inverting the logit transformation, multiplying by the number of eggs set and rounding to an integer.

## 4) SIMULATIONS

Three variables were analyzed in the simulation study: i) number of eggs laid, ii) proportion of non-cracked eggs and iii) proportion of eggs set which hatch.

The analysis is different for the variables which are expressed as proportions

and the number of eggs laid. For the proportion variables the analysis begins by transforming and weighting the variables while the number of eggs laid was not transformed or weighted. The analysis of all variables then proceeds to a test which searches for the lowest dose which shows a significant difference from the control.

The simulation program was written in FORTRAN. The random numbers used in the simulation used a uniform random number generator and were converted to univariate normal random numbers using the subroutine TRPNRM both given in Bradley et. al. (1983). A set of three independent normal random numbers were then converted into a trivariate normal distribution using a Cholesky decomposition of the required covariance matrix (Bradley et. al. 1983). The program was run on an 486 microcomputer.

The next two sections describe the transformations and weightings which were applied to the analysis of proportion data. The next section, 4.3), describes the various test procedures used to search for the lowest significant dose.

#### 4.1) Transformations studied

Proportions can be compared among treatment groups directly or transformed prior to the analysis. Two transformations were considered: the logit transformation and the Freeman-Tukey Binomial transformation.

The logit transformation of a proportion ( $p$ ) is defined as

$$\begin{aligned}\text{LOGIT}(p) &= \log[p/(1-p)] && (\text{if } 0 < p < 1) \\ &= \log[(1/4n)/(1-1/4n)] && (\text{if } p=0) \\ &= \log[(1-1/4n)/(1/4n)] && (\text{if } p=1)\end{aligned}$$

where  $n$  is the denominator used to calculate the proportion. The two special definitions for  $p=0$  and  $p=1$  were an arbitrary choice which has been found practical for transformation of Binomial random variables.

A transformation which is often recommended for proportions is the Freeman-Tukey Binomial (FTB) transformation which is designed to homogenize the variance of a binomial variable for different values of the mean. The Freeman-Tukey Binomial transformation of a variable  $p$  is defined as

$$FTB(p) = \frac{\text{ARCSIN} \left[ \text{SQRT} \left( x / (n + 1) \right) \right] + \text{ARCSIN} \left[ \text{SQRT} \left( (x + 1) / (n + 1) \right) \right]}{2}$$

where  $x$  denotes the numerator and  $n$  the denominator used in calculating the proportion.

#### 4.2) Weightings studied

The logit and FTB transformations are used to create homogeneous variances among treatment groups and to make the distribution of the proportions to be closer to the normal distribution. They do not compensate for differing variance caused by the number of observations used in determining the proportion. A complementary manner of handling the problem of heterogeneity of variance is to use a weighting factor when calculating means. Let  $p_{ij}$  denote the  $j$ -th observation in treatment  $i$  and  $n_{ij}$  denote the denominator of the proportion. The following weighting schemes were considered

Equal weighting (EQL): (This scheme would be appropriate if the within pen variance was much smaller than the among pen variance.

$$w_{ij} = 1$$

Binomial weighting (BIN): This scheme would be appropriate if there were no among pen variance.

$$w_{ij} = n_{ij}$$

Inverse of the estimated variance weighting (IPC): (This is weighting scheme intermediate between binomial and equal weighting which balances the among and within pen variances.)

$$w_{ij} = n / [(n-1)c + 1]$$

$$\text{where } c = s_a^2 / (s_a^2 + s_w^2)$$

and  $s_a^2$  and  $s_w^2$  are the among and within pen variance components estimated from a one-way ANOVA on the response of individual eggs pooled over treatments. The variance components within each treatment being a linear estimate based on the expected mean squared error for the ANOVA with  $s_a^2$  set equal to zero if the estimate is negative. Possible drawbacks with this scheme are i) the number of pens may be too small to provide an accurate estimate of the intrapen correlation

and ii) the weighting term is a random variable which is correlated with the observations and hence violates the assumptions used to derive the theory on which the estimator is based.

Using the estimated variance as a weighting term requires that the individual eggs can be used to calculate the intrapen correlation. This is not possible for the transformed proportions since the transformation cannot be applied to the response for the individual eggs. Table 6 shows the combinations of transformations and weighting schemes used.

The estimated treatment mean for each variable is a weighted mean of the observations for each pen i.e.

$$\bar{z}_{i.} = \frac{\sum_{j=1}^{n_i} w_{ij} z_{ij}}{w_{i.}}$$

#### 4.3) Tests studied

The objective of the testing procedure is to determine the lowest dose which has a statistically significant effect. Several test procedures are available which search for the lowest significant dose. Each test has the property that if a dose level is declared significantly different from the control then all higher dose levels are also significantly different from the control.

**SEQUENTIAL T-TEST (SEQT):** Test the highest dose against the control group using a t-test with a pooled estimate of variance.

$$t = \frac{\bar{z}_{i.} - \bar{z}_{1.}}{s \text{ SQRT } \left[ 1/w_{i.} + 1/w_{1.} \right]}$$

If the test is significant then run the test at the next lower dose. Stopping when the test is no longer significant.

**SEQUENTIAL REGRESSION TEST (SEQR):** Run a simple linear regression of the four treatment groups as though the doses were equally spaced (i.e. the doses were 1, 2, 3 and 4). The test for significance of the trend is based on the pooled

estimate of variance instead of the residual sum of squares from the regression.

$$\hat{b} = \frac{\sum_{i=1}^I w_{i.} (\bar{z}_{i.} - \bar{z}_{..})(i - r)}{\sum_{i=1}^I w_{i.} (i - r)^2}$$

where

$$r = \frac{\sum_{i=1}^I i w_{i.}}{\sum_{i=1}^I w_{i.}}$$

The significance of the trend with dose is assessed through a t-test

$$t = \frac{\hat{b}}{s \text{ SQRT} \left[ \sum_{i=1}^I w_{i.} (i - r)^2 \right]}$$

The test is run initially with  $I=4$  and if it is significant then the highest dose is discarded and the test is repeated with the remaining groups. This continues until the test is no longer significant.

**WILLIAM'S TEST (WILL):** William's test is based on assuming the treatment means should decrease monotonically with increasing dose. If the treatment means do not follow the assumed pattern then they are amalgamated until the conjectured trend appears. (Amalgamation is done by combining the treatment groups discordant with the assumed trend.)

$$t_w = \frac{e_{i.} - \bar{z}_{i.}}{s \cdot \text{SQRT} \left[ 1 / w_{i.} + 1 / w_{I.} \right]}$$

where  $e_{i.}$  denotes the amalgamated estimate of the mean for dose group I.

The above test statistic is compared with the critical value for William's test (William, 1971). This critical value is based on the assumption of equal sample sizes (weights) within each group. Since the group weights may be different the test may be biased. The test is done initially with all treatment groups. If the test is significant the highest dose is discarded and the test repeated with the remaining groups. This continues until the test is non-significant.

**SEQUENTIAL BARTHOLOMEW'S  $E^2$  TEST (EBAR):** This test is similar to William's test in that it is based on the amalgamated means. The test statistic is

$$\bar{E}^2 = \frac{\sum_{i=1}^I w_{i.} (e_{i.} - \bar{z}_{i.})^2}{\text{SQRT} \left[ d s^2 + \sum_{i=1}^I w_{i.} (\bar{z}_{i.} - \bar{z}_{..})^2 \right]}$$

where  $d$  is the number of degrees of freedom in the estimate of  $s^2$ . The critical value for the test can be calculated using a procedure described by Roth (1983). The test is done sequentially with starting with the all doses. If the test is significant the highest dose is discarded and the test repeated until it is no longer significant. The equation for the above test is slightly different than that usually presented. This was done to allow pooling of the variance estimate from all doses in the estimation of variance (Marcus 1976).

**BASIN CONTRAST (BASN):** This test is based on assuming there is no treatment effect below a threshold dose and a linear decline in the treatment mean above the threshold (Ruberg, 1989). The test statistic is

$$c = \max (c_L, c_M, c_H)$$

where

$$c_L = \frac{6\bar{z}_1 + 2\bar{z}_2 - 2\bar{z}_3 - 6\bar{z}_4}{s \text{ SQRT } \left[ 36/w_1 + 4/w_2 + 4/w_3 + 36/w_4 \right]}$$

$$c_M = \frac{3\bar{z}_1 + 3\bar{z}_2 - \bar{z}_3 - 5\bar{z}_4}{s \text{ SQRT } \left[ 9/w_1 + 9/w_2 + 1/w_3 + 25/w_4 \right]}$$

$$c_H = \frac{\bar{z}_1 + \bar{z}_2 + \bar{z}_3 - 3\bar{z}_4}{s \text{ SQRT } \left[ 1/w_1 + 1/w_2 + 1/w_3 + 9/w_4 \right]}$$

The test statistic is compared against a tabulated value to determine if there is a significant treatment effect. If there is a significant treatment effect then the lowest significant dose is determined as follows if  $c = c_H$  then H is the lowest significant dose. If  $c = c_M$  then M is the lowest significant dose and if  $c = c_L$  then L is the lowest significant dose.

This test is only tabulated for equal sample size (weights) within each treatment group. Since the weights may not be identical for all treatments the test may be biased.

#### 4.4) Analysis of results

Each experimental design was run separately. The sample sizes run for each experiment age given in Table 7. The smallest sample size was set equal to the most commonly used sample size currently used and the largest sample size was selected through preliminary runs to assess which sample size was required to give a power of 80% for the proportion of eggs which hatch. The simulations were done by generating a data set for the largest requested sample size and working with only a portion of the data set for the calculations for smaller sample sizes. Thus the results from different sample sizes are correlated.

All transformations, weightings and tests were run for each data set. Thus the results from the different transformations, weightings and tests are correlated. In order to allow statistical comparisons among the results the simulations were run in 5 blocks of 1000.

Within each block the minimum sample size required to attain a probability 80% was determined as follows. A logistic regression was fitted to the simulated probabilities against the sample size and the fitted curve was interpolated to determine when the power 0.8. The estimated sample sizes were then analyzed using an ANOVA as described above.

## 5) RESULTS

### 5.1) Estimated significance level of tests

The first step was to assess if the tests were running at the nominal 0.05 significance level. A simulation was run assuming no treatment effect (Pattern 1). The results are shown in Table 8. If the test operated at the nominal 0.05 level of significance then the proportion of times each test gave a significant result would be described by the binomial distribution. With  $n=5000$  and  $p=0.05$  the binomial is well approximated by the normal distribution. The probability that an observed result is significantly above the nominal significance level can be determined using a one-sided z-test. The overall significance level for the multiple comparisons within each experimental design were controlled using the Dunn-Sidak inequality. Hence the 5 comparisons for number of eggs laid were run at the  $1-(1-0.05)^{1/5}$  significance level while the 35 comparisons for the proportion variables were run at the  $1-(1-0.05)^{1/35}$  significance level. A result was considered above the 0.05 significance level if it exceeded 0.057 for eggs laid or 0.059 for the proportion variables. The simulation results within each experiment and test have a positive correlation due to each analysis being run on the same simulated data sets. Thus the above test is generous in accepting results as meeting the nominal significance level.

#### 5.1.1) Bobwhite Quail: 1:1 caging: 8 week test: 16 pens

For eggs laid, the significance level was not significantly above the nominal 0.05 level for any test.

For proportion of non-cracked eggs, the significance level was below the nominal level for all analyses except when the logistic transformation was used with binary weighting with the sequential regression or William's test.

For proportion of eggs hatched over eggs set, the significance level was above the nominal level for almost all analyses based on Binomial weighting but was below the nominal significance level for all other weighting procedures.

#### 5.1.2) Bobwhite quail: 1:1 caging: 12 weeks on test: 16 pens

For eggs laid, the significance level was not significantly above the nominal 0.05

level for any test.

For proportion of non-cracked eggs, the significance level was below the nominal level for all analyses except when the logistic transformation was used with binary weighting with the Bartholomew's test (EBAR).

For proportion of eggs hatched over eggs set, the significance level was above the nominal level for almost all analyses based on Binomial weighting but was below the nominal significance level for all other weighting procedures.

#### 5.1.3) Bobwhite Quail: 1:2 caging: 8 week test: 14 pens

For eggs laid, the significance level was not significantly above the nominal 0.05 level for any test.

For proportion of non-cracked eggs, the significance level was below the nominal level for all analyses except when the logistic transformation was used with binary weighting with the sequential t-test (SEQT), sequential regression (SREG) or William's test (WILL).

For proportion of eggs hatched over eggs set, the significance level was above the nominal level for almost all analyses based on Binomial weighting except for Bartholomew's test (EBAR) but was below the nominal significance level for all other weighting procedures,

#### 5.1.4) Bobwhite Quail: 1:2 caging: 12 week test: 14 pens

For all 3 variables: eggs laid, proportion of non-cracked eggs and proportion of eggs hatched over eggs set, the significance level was not significantly above the nominal 0.05 level for any test.

#### 5.1.5) Mallard: 1:1 caging: 8 week test: 16 pens

For all 3 variables: eggs laid, proportion of non-cracked eggs and proportion of eggs hatched over eggs set, the significance level was not significantly above the nominal 0.05 level for any test.

#### 5.1.6) Mallard: 2:5 caging: 8 week test: 6 pens

For all 3 variables: eggs laid, proportion of non-cracked eggs and proportion of eggs hatched over eggs set, the significance level was not significantly above the nominal 0.05 level for any test.

#### 5.1.7) Mallard: 2:5 caging: 12 week test: 6 pens

For all 3 variables: eggs laid, proportion of non-cracked eggs and proportion of eggs hatched over eggs set, the significance level was not significantly above the nominal 0.05 level for any test.

## **5.2) Estimated significance level for partial null hypothesis**

For three of the treatment patterns: 2, 3, and 5, there was a threshold dose below which the treatment had no effect. Simulations were run for each of these three patterns setting  $f=0.8$ . The proportions of time the highest dose below the threshold was found significantly different from the control are shown in Table 9 with a typical current sample size for each experimental design. The results were similar for other sample sizes.

### **5.2.1) Bobwhite Quail: 1:1 caging: 8 week test: 16 pens**

For number of eggs laid, the basin contrast significance levels for the partial null hypothesis were above the nominal level.

For proportion of non-cracked eggs, the significance levels for the Basin contrast were above the nominal level for treatment pattern 3 and often for treatment pattern 5.

For the proportion of eggs hatched over eggs set, the significance levels for the basin contrast were above the nominal levels as well as for the logistic transformation with binary weighting for treatment patterns 2 and 5.

### **5.2.2) Bobwhite Quail: 1:1 caging: 12 week test: 16 pens**

For number of eggs laid and the proportion of non-cracked eggs, the basin contrast significance levels for the partial null hypothesis were above the nominal level. In addition for the proportion of non-cracked eggs the nominal significance level was exceeded for treatment pattern 2 with the logit transformation and binary weighting for all test procedures except EBAR.

For the proportion of eggs hatched over eggs set, the significance levels for the basin contrast were above the nominal levels as well as for the logistic transformation with binary weighting for treatment patterns 2 and 5.

### **5.2.3) Bobwhite Quail: 1:2 caging: 8 week test: 14 pens**

For number of eggs laid and the proportion of non-cracked eggs, the basin contrast significance levels for the partial null hypothesis were above the nominal level. In addition for the proportion of non-cracked eggs the nominal significance level was exceeded for treatment patterns 2 and 5 the logit transformation with

binary weighting for all test procedures.

For the proportion of eggs hatched over eggs set, the significance levels for the basin contrast were above the nominal levels as well as for the logistic transformation with binary weighting for the sequential regression test (SREG) and Bartholomew's test (EBAR) for treatment pattern 2.

#### 5.2.4) Bobwhite Quail: 1:2 caging: 12 week test: 14 pens

For number of eggs laid, the proportion of non-cracked eggs and the proportion of eggs hatched over eggs set, the basin contrast significance levels for the partial null hypothesis were above the nominal level.

#### 5.2.5) Mallard: 1:1 caging: 8 week test: 16 pens

For number of eggs laid and the proportion of eggs hatched over eggs set, all test procedures gave significance levels for the partial null hypothesis were above the nominal level.

For the proportion of non-cracked eggs, the basin contrast exceeded the nominal significance level for treatment pattern 3 and occasionally for treatment pattern 5. The nominal significance levels also were exceeded for treatment pattern 5 with the logit transformation and binary weighting for all test procedures.

#### 5.2.6) Mallard: 2:5 caging: 8 week test: 6 pens

For number of eggs laid and the proportion of eggs hatched over eggs set, the basin contrast significance levels for the partial null hypothesis were above the nominal level.

For the proportion of non-cracked eggs, the basin contrast exceeded the nominal significance level for treatment patterns 2 and 3 and usually for treatment pattern 5.

#### 5.2.7) Mallard: 2:5 caging: 12 week test: 6 pens

For number of eggs laid and the proportion of eggs hatched over eggs set, the basin contrast significance levels for the partial null hypothesis were above the nominal level.

For the proportion of non-cracked eggs, the basin contrast exceeded the nominal significance level for treatment pattern 3 and often for treatment patterns 2 and 5.

### 5.2.8) General comments

It can be seen that the Basin contrasts (BASN) operated at a level substantially above the nominal 0.05 level for LAID and HA/SE. For NC/LA the results are somewhat less consistent but for every transformation and weighting there was at least one treatment pattern for which the results exceeded the nominal level. The reason for this is unknown but it is possible that the Basin contrast is sensitive to departures from normality or to the imbalance in sample size. Departures from the normal distribution were caused by the presence of outliers and the rounding to integers which occurred in the simulation. The imbalance between treatment groups was caused by outliers for some variables e.g. if the number of eggs laid was zero then a data point would be missing for the variable HA/SE. The basin contrast will not be included in further analysis.

### 5.3) Sample size requirement to attain 80% power

Examples of the logistic curves used to estimate the minimum sample size required to attain power=0.8 are shown in Figures 2 and 3. The probabilities of rejection (vertical axis) are logit transformed but are labelled with the original probability values which are non-linear in this scale. The results of the simulations are shown as open circles, the logistic curves fitted to the 5 independent simulations are shown as straight lines and the estimated sample size required to attain 80% power are shown as filled circles.

This example shows the probability of rejecting the high dose number of eggs laid and proportion of non-eggs which hatch for Bobwhite quail using 1:1 caging and 8 weeks duration and treatment pattern 2. The test procedure WILL on untransformed and equal weighted data is presented but curves for other variables and analyses were similar. It can be seen that the straight line fits the data well. There is no theoretical justification for this analysis but it provides a reasonable method of interpolating between the data points.

The estimated sample size to provide 80% power is shown for each variable, transformation, weighting procedure and test procedure in Table 10. The sample sizes are not integers since they have been derived as fitted values on curves. The values must be rounded upward to the nearest integer to provide numbers which can be used in the design of experiments but the unrounded numbers are presented since it allows the required sample sizes to be ordered more completely.

The sample sizes for the simulations was selected by running some preliminary simulations on the variable HA/SE. In evaluating the results it can be seen that the required sample size could usually be calculated by interpolation for HA/SE i.e. that selected sample sizes bounded the required sample size. However, for the variable LAID the results often had to be extrapolated to a much larger sample

size than those used in the simulation and the resulting calculations should be thought of as suggestive but definitive. For the variable NC/LA the power was often estimated to be at or near 1.00 for all sample sizes and in many instances it was impossible to extrapolate to the sample size required for 80% power.

For each experimental design the maximum required sample size for each test, transformation and weighting over the 8 patterns was determined. This usually occurred for treatment pattern 8. The results of the analysis are summarized in Table 11. The instances in which pattern 8 did not impose the largest sample size are noted in Table 8. In several instances accomodating pattern 8 caused a substantial increase in sample size requirements over those for the other patterns.

The sample sizes required to give 80% power of detecting the lowest significant dose were smallest for NC/LA and highest for LAID with HA/SE intermediate between them.

In most instances William's test required the smallest sample size but Bartholomew's test (EBAR) provided very similar sample size requirements. The sequential t-test and the sequential regression test were also similar in sample size requirements but results were appreciable higher than those for William's or Bartholomew's tests.

In analyzing HA/SE the logit transformation with equal weighting results in the smallest sample size requirement for all experiments except Bobwhite quail in 1:0 caging. For these designs untransformed data with equal or IPC weighting provided the smallest sample size requirement.

In analyzing NC/LA in many instances it was not possible to determine minimum sample size requirements because the selected sample sizes were inappropriate. However, analysis based on the logit transformation with equal weighting resulted in the smallest sample size for all designs which could be examined.

## 6) DISCUSSION

Developing sample size requirements for dichotomous variables can be difficult. Piegorish (1991) points out that the standard large sample approximations to the binomial distribution can produce anticonservative confidence intervals unless combined group sizes are above 300. This suggests that there may be problems in using large sample approximations as a means of determining sample sizes to achieve required power levels.

One can calculate the power of a statistical test given the sample size or one can determine the sample size given a power requirement. Many statistical papers

which compare the power of various statistical procedures (e.g. Marcus, 1986) arrive at conclusions as to which test is the most powerful in a given situation but do not provide required sample sizes for a given power. This is particularly true in testing for the NOEL. There are no papers which describe how large a sample must be for the NOEL level to be detected reliably.

### 6.1) Extra-Binomial Variability

For AR studies the problem is more complex than the analysis of a simple dichotomous response due to the presence of extra-binomial variability. The presence on such variability has been well documented for teratogenicity studies on rats (Weil, 1970; Haseman and Soares 1976). Many of the designs for avian reproduction studies involve gang caging of males with several females and hence the litter effects are replaced by the analogous pen effects. In addition for the AR tests the birds are thought to be theoretically capable of producing one egg per day per female in the pen. Although this limit is not achieved by the birds on test the sample sizes per pen are much larger than typically seen in litters in teratogenicity studies on rodents. Because of this the extra-binomial variance component is substantially larger fraction of the overall variance in AR than in rodent studies and this may mean that conclusions derived for rodent teratogenicity studies are not appropriate for AR studies.

On manner of handling the extra-binomial variability is through weighting the data from different pens and several papers have examined the efficiency of different weighting schemes (Cochran, 1943; Weiler and Culpin, 1970; Kleinman, 1973; Birkes et. al. 1981). Many of these papers deal with the analysis of agricultural or rodent toxicity studies which deal with fewer units per litter.

An alternative manner of dealing with the problem of extra-binomial variance is to assume it has a distributional form. Many models have been proposed and a good review of these is given by Haseman and Kupper (1979). One of the most studied is the Beta-Binomial model which has proved to be mathematically tractable. Studies on the Beta-Binomial Model have shown that: i) it provides a substantially improved fit to data for teratogenic studies on rats but that there remains a significant lack of fit to real-life data, ii) that the analysis is sensitive to departures from the theoretical distribution and iii) that it produces inflated type I error rates when applied to real-world data (Hasemann and Soares, 1979). Because of these difficulty in justifying the Beta-Binomial model it was not included in the simulation study.

Gladden (1979) has studied the properties of the jackknife estimator and found it to be of comparable power to the Mann-Whitney U static and a t test on a Freeman-Tukey transformed probability but that is was somewhat less powerful than these other techniques when the litter size was affected by the treatment.

Randomization tests have also been proposed as an effective manner of analyzing this type of experiment (Crump and Howe, 1980). Randomization tests can be used with any test statistic although they must be applied carefully to multiple-comparison problems (Petronidas and Gabriel, 1983). Power calculations for randomization tests are difficult and are beyond the scope of the present paper.

## **6.2) Determining NOEL**

There are many test procedures which identify a NOEL. For AR studies it is necessary to select a method which is readily available i.e. not requiring complicated computations or for which it is difficult to obtain tables of critical values. In this paper, some simple procedures (SEQT, SEQR and WILL) as well as some more complex test procedures (EBAR and BASIN) were examined.

An alternative to identifying a NOEL is to fit a dose response curve and to interpolate to determine the dose giving rise to a particular increase over control. Chen and Kodel (1989) propose using a Beta-Binomial model to describe the results at each dose level and a Weibull dose-response curve. Alternatively a logistic dose-response model was studied by Kupper et. al. (1986). These models provide valuable appreciation of what aspects of the data distribution can bias parameter estimation but because the models lack any biological justification the identified levels giving a particular response must be viewed with suspicion. These papers examine litter sizes which are common for rodent teratologic studies and may not be applicable to AR studies.

It was reported by Kupper et. al. (1986) that if intralitter correlations are dose dependent then the assumption of a common intralitter correlation can bias the parameter estimation. Gladden (1986) found through a simulation study that if the treatment reduced litter size as well as the proportion surviving then the power of the jackknife procedure was also reduced. There is a need to evaluate the impact of treatment effect in other variables on the power of these tests and the model presented here is quite suited for doing such a comparisons. This will be the subject of further studies with this model.

## **6.3) Treatment Effects and Caging Strategies**

The simulation study done here assumes that the treatment effect will simply reduce the response for all pens in treatment group similarly. In an actual experiment the treatment might affect individuals differentially. This would make the results of the experiment more variable and would require a larger sample size to detect reliably.

The use of pens with more than one male and female could mitigate the problem of differential response by increasing the probability that at least one susceptible

individual was present in each pen. Alternatively pens with more than one individual could mask the treatment effect. E.g. if a treatment sometimes affected fertility of the male then the 2:5 caging arrangement used for mallard allows the situation in which one male was affected in a pen while the other was not. The unaffected male might be able to ensure that hatching rates appeared normal in the pen. Such a situation would reduce the ability of the experiment to detect the treatment effect since only those pens which through chance had two susceptible males would exhibit the effect. Thus the mechanism of the treatment effect must be considered in making decisions about caging strategy.

The analysis in this report provides a manner of comparing caging strategy based on number of pens required to have the same power for the resulting analysis. However, alternate considerations must then come into play to select the preferred design. Two items to consider are i) the cost and ii) the number of animals on test. For an analysis of proportion hatched for mallards, using 34 pens in 1:1 caging is equivalent to using 14 pens in 2:5 caging. First, the cost of these two designs could be compared by someone actively engaged in running these experiments. Second, animal welfare concerns would note that 1:1 caging requires 68 birds per treatment while 2:5 caging requires 98 birds.

## 7) CONCLUSIONS

- i) Sample size requirements are different for the three variables studied. The order of the sample size requirements is (proportion of non-cracked eggs) less than (proportion of eggs hatching) less than (number of eggs laid).
- ii) The most efficient procedure to search for the NOEL is William's test with Bartholomew's test a close second.
- iii) The most difficult treatment pattern to detect the NOEL for is pattern 8 in almost all experimental conditions. Having to guard against pattern 8 causes an appreciable increase in the sample size requirement over the other treatment patterns.
- iv) For the proportion of non-cracked eggs and the proportion of eggs hatching the most efficient data analysis is done through a logit transformation of the data with equal weighting except for experiments with Bobwhite quail in 1:2 caging for which the probability should not be transformed and equal or estimated intrapen correlation weighting should be used.
- v) The required sample size to give an 80% probability of detecting the NOEL for the 7 active treatment patterns (i.e. ignoring pattern 1 which is no treatment effect) considered is shown in Table 12. The salient conclusions of the analysis are that:
  - The current number of pens utilized is much too low and does not result in a test of adequate statistical power.
  - For same species and caging, increasing the weeks on test from 8 to 12 reduces the required number of pens for analysis of eggs laid but increases it for proportion hatched.
  - For mallards placing more animals in the cage reduces the sample size for eggs laid and proportion hatched while for bobwhite quail placing more animals in the cage reduces the sample size for eggs laid but causes little or no reduction in sample size for proportion hatched.

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Table 1: Current design of AR tests: Number of cages.

SPECIES	CAGING (M:F)	MINIMUM REQUIRED CAGES a	NUMBER OF CAGES						
			5	6	12	14	16	17	20
Bobwhite	1:1	>12 b					13	1	4
	1:2	12			1	4		1	1
Mallard	1:1	>12 b					12	1	
	2:5	5	1	10					

a - USEPA

b - an exact number is not given but 25 is indicated as a possible requirement

- table entries show frequency of each type of design

Table 2: Current design of AR tests: Number of weeks on test

SPECIES	CAGING (M:F)	WEEKS ON TEST						
		8	9	10	11	12	13	
Bobwhite	1:1	2	5	7	1	3		
	1:2					6	1	
Mallard	1:1	8	3	2				
	2:5			1		9	1	

- table entries show frequency of each type of design

Table 3: Number of background studies for each experimental design evaluated

SPECIES	CAGING	WEEKS ON TEST	
		8	12
Bobwhite	1:1	18 (304)	3 ( 60)
	1:2	7 (105)	7 (105)
Mallard	1:1	13 (208)	
	2:5	11 ( 65)	10 ( 59)

- table entries show number of studies (pens)

Table 4: Parameters fitted to trivariate distribution for experiments using bobwhite quail

PARAMETER	1:1 CAGING		1:2 CAGING		
	8 WEEKS	12 WEEKS	8 WEEKS	12 WEEKS	
DISTRIBUTION MEAN					
LAID	32.3	52.8	41.3	71.4	
Logit(NC/LAID)	3.23	1.89	2.00	2.03	
Logit(HA/SET)	1.66	1.36	1.05	1.13	
COVARIANCE MATRIX					
LAID	X LAID	176.616	382.270	277.230	523.460
LAID	X Logit(NC/LAID)	8.517	-1.654	-1.333	0.824
LAID	X Logit(HA/SET)	3.213	13.503	1.968	4.704
Logit(NC/LAID)	X Logit(NC/LAID)	11.820	9.362	9.389	11.035
Logit(NC/LAID)	X Logit(HA/SET)	-0.049	0.471	-1.925	-0.197
Logit(HA/SET)	X Logit(HA/SET)	7.347	7.252	4.644	4.890
INTRAPEN CORRELATION					
Logit(NC/LAID)		0.073	0.050	0.063	0.060
Logit(HA/SET)		0.134	0.192	0.158	0.179
PROPORTION OF OUTLIERS					
LAID		0.080	0.080	0.02	0.04
NC/LAID		0.000	0.000	0.01	0.01
HA/SET		0.007	0.020	0.03	0.03
OUTLIER MEAN					
LAID		0.048	0.670	0.000	0.50
NC/LAID		--	--	0.320	0.32
HA/SET		0.053	0.036	0.013	0.009

Table 5: Parameters fitted to trivariate distribution for experiments using mallards

	1:1 CAGING	2:5 CAGING		
PARAMETER	8 WEEKS	8 WEEKS	12 WEEKS	
DISTRIBUTION MEAN				
LAID	42.3	123.0	164.0	
Logit(NC/LAID)	3.81	2.99	3.06	
Logit(HA/SET)	1.06	0.45	0.038	
COVARIANCE MATRIX				
LAID	X LAID	80.478	882.913	1750.45
LAID	X Logit(NC/LAID)	3.622	-24.303	-30.042
LAID	X Logit(HA/SET)	4.069	-0.203	-12.282
Logit(NC/LAID)	X Logit(NC/LAID)	23.647	23.429	23.674
Logit(NC/LAID)	X Logit(HA/SET)	0.122	-0.172	-0.262
Logit(HA/SET)	X Logit(HA/SET)	4.950	4.997	4.835
INTRAPEN CORRELATION				
Logit(NC/LAID)		0.013	0.014	0.008
Logit(HA/SET)		0.191	0.039	0.041
PROPORTION OF OUTLIERS				
LAID		0.034	0.000	0.000
NC/LAID		0.005	0.000	0.000
HA/SET		0.007	0.000	0.000
OUTLIER MEAN				
LAID		1.428	--	--
NC/LAID		0.830	--	--
HA/SET		0.022	--	--

Table 6: Transformations and weighting schemes studied

Transformation	Weighting		
	Equal	Binomial	Est. Var.
None	X	X	X
Logit	X	X	
FTB	X	X	

$\bar{X}$  - denotes a combination which was included in the evaluation

Table 7: Number of pens per treatment group for each experimental design

SPECIES	CAGING (M:F)	CURRENT TYPICAL SAMPLE SIZE	DURATION (WEEKS)	PENS PER TREATMENT
Bobwhite	1:1	16	8	16(2)30
			12	16(4)40
	1:2	14	8	14(4)38
			12	14(4)38
Mallard	1:1	12	8	12(4)30
	1:2	6	8	6(2)16
			12	6(2)16

- table entries show smallest sample size (step size) largest sample size

Table 8: Probability of declaring the high dose significantly different from control for treatment pattern 1 using current sample sizes.

SPECIES	CAGE	WEEKS	PENS	VAR	TRANS.	WT.	TEST PROCEDURE				
							SEQT	SEQR	WILL	BASN	EBAR
BOBWHITE 1:1	8	16	LAID	NON	EQL		0.051	0.050	0.050	0.039	0.040
			NC/LA	FBT	BIN		0.051	0.054	0.049	0.046	0.041
			NC/LA	FBT	EQL		0.050	0.051	0.048	0.050	0.042
			NC/LA	LGT	BIN		0.058	0.060	0.060	0.052	0.048
			NC/LA	LGT	EQL		0.051	0.050	0.049	0.048	0.043
			NC/LA	NON	BIN		0.045	0.047	0.041	0.042	0.032
			NC/LA	NON	EQL		0.052	0.052	0.046	0.048	0.038
			NC/LA	NON	IPC		0.045	0.047	0.039	0.038	0.030
			HA/SE	FTB	BIN		0.069	0.069	0.069	0.062	0.062
			HA/SE	FTB	EQL		0.054	0.053	0.051	0.047	0.039
			HA/SE	LGT	BIN		0.068	0.069	0.070	0.065	0.064
			HA/SE	LGT	EQL		0.053	0.052	0.050	0.045	0.040
			HA/SE	NON	BIN		0.067	0.065	0.064	0.061	0.057
			HA/SE	NON	EQL		0.053	0.053	0.049	0.045	0.040
			HA/SE	NON	IPC		0.051	0.051	0.049	0.046	0.040
BOBWHITE 1:1	12	16	LAID	NON	EQL		0.046	0.044	0.045	0.039	0.037
			NC/LA	FBT	BIN		0.058	0.059	0.057	0.053	0.050
			NC/LA	FBT	EQL		0.052	0.053	0.048	0.043	0.039
			NC/LA	LGT	BIN		0.059	0.056	0.057	0.051	0.050
			NC/LA	LGT	EQL		0.051	0.054	0.051	0.045	0.040
			NC/LA	NON	BIN		0.054	0.058	0.053	0.054	0.047
			NC/LA	NON	EQL		0.049	0.056	0.047	0.044	0.037
			NC/LA	NON	IPC		0.048	0.053	0.046	0.044	0.036
			HA/SE	FTB	BIN		0.068	0.067	0.066	0.062	0.059
			HA/SE	FTB	EQL		0.051	0.053	0.047	0.045	0.040
			HA/SE	LGT	BIN		0.069	0.071	0.069	0.066	0.063
			HA/SE	LGT	EQL		0.052	0.054	0.051	0.046	0.044
			HA/SE	NON	BIN		0.067	0.067	0.065	0.059	0.056
			HA/SE	NON	EQL		0.049	0.050	0.046	0.045	0.040
			HA/SE	NON	IPC		0.048	0.052	0.047	0.044	0.041

Table 8: continued

SPECIES	CAGE	WEEKS	PENS	VAR	TRANS.	WT.	TEST PROCEDURE				
							SEQT	SEQR	WILL	BASN	EBAR
BOBWHITE 1:2	8	14	LAID	NON	EQL	0.055	0.054	0.051	0.044	0.045	
			NC/LA	FBT	BIN	0.057	0.057	0.057	0.054	0.051	
			NC/LA	FBT	EQL	0.047	0.050	0.048	0.043	0.039	
			NC/LA	LGT	BIN	0.060	0.060	0.061	0.054	0.051	
			NC/LA	LGT	EQL	0.048	0.051	0.051	0.044	0.041	
			NC/LA	NON	BIN	0.053	0.056	0.056	0.053	0.047	
			NC/LA	NON	EQL	0.045	0.049	0.045	0.042	0.035	
			NC/LA	NON	IPC	0.043	0.048	0.045	0.040	0.035	
			HA/SE	FTB	BIN	0.066	0.070	0.066	0.066	0.059	
			HA/SE	FTB	EQL	0.049	0.048	0.047	0.042	0.037	
			HA/SE	LGT	BIN	0.067	0.067	0.064	0.067	0.058	
			HA/SE	LGT	EQL	0.052	0.050	0.047	0.043	0.036	
			HA/SE	NON	BIN	0.064	0.067	0.064	0.064	0.056	
			HA/SE	NON	EQL	0.047	0.047	0.045	0.042	0.036	
			HA/SE	NON	IPC	0.048	0.046	0.045	0.042	0.035	
BOBWHITE 1:2	8	14	LAID	NON	EQL	0.050	0.048	0.046	0.044	0.039	
			NC/LA	FBT	BIN	0.051	0.050	0.051	0.046	0.042	
			NC/LA	FBT	EQL	0.047	0.045	0.045	0.040	0.035	
			NC/LA	LGT	BIN	0.050	0.048	0.050	0.048	0.040	
			NC/LA	LGT	EQL	0.045	0.044	0.044	0.039	0.034	
			NC/LA	NON	BIN	0.049	0.051	0.047	0.048	0.039	
			NC/LA	NON	EQL	0.048	0.045	0.045	0.039	0.033	
			NC/LA	NON	IPC	0.048	0.045	0.045	0.040	0.034	
			HA/SE	FTB	BIN	0.055	0.058	0.054	0.055	0.048	
			HA/SE	FTB	EQL	0.050	0.052	0.048	0.045	0.036	
			HA/SE	LGT	BIN	0.057	0.058	0.055	0.056	0.045	
			HA/SE	LGT	EQL	0.048	0.052	0.047	0.047	0.036	
			HA/SE	NON	BIN	0.054	0.058	0.054	0.054	0.047	
			HA/SE	NON	EQL	0.051	0.050	0.045	0.046	0.034	
			HA/SE	NON	IPC	0.050	0.050	0.046	0.046	0.035	
MALLARD 1:1	8	16	LAID	NON	EQL	0.050	0.048	0.048	0.046	0.037	
			NC/LA	FBT	BIN	0.050	0.048	0.047	0.039	0.033	
			NC/LA	FBT	EQL	0.050	0.049	0.047	0.041	0.035	
			NC/LA	LGT	BIN	0.053	0.050	0.051	0.043	0.038	
			NC/LA	LGT	EQL	0.054	0.049	0.049	0.040	0.035	
			NC/LA	NON	BIN	0.043	0.042	0.038	0.037	0.029	
			NC/LA	NON	EQL	0.044	0.046	0.038	0.039	0.031	
			NC/LA	NON	IPC	0.042	0.043	0.037	0.039	0.030	
			HA/SE	FTB	BIN	0.058	0.056	0.054	0.049	0.048	
			HA/SE	FTB	EQL	0.052	0.054	0.050	0.042	0.041	
			HA/SE	LGT	BIN	0.058	0.055	0.057	0.051	0.047	
			HA/SE	LGT	EQL	0.052	0.053	0.050	0.042	0.040	
			HA/SE	NON	BIN	0.056	0.055	0.053	0.048	0.047	
			HA/SE	NON	EQL	0.052	0.054	0.052	0.044	0.043	
			HA/SE	NON	IPC	0.052	0.053	0.051	0.043	0.043	

Table 8: continued.

SPECIES	CAGE	WEEKS	PENS	VAR	TRANS.	WT.	TEST PROCEDURE				
							SEQT	SEQR	WILL	BASN	EBAR
MALLARD	2:5	8	6	LAID	NON	EQL	0.055	0.058	0.055	0.043	0.040
				NC/LA	FBT	BIN	0.053	0.054	0.052	0.051	0.042
				NC/LA	FBT	EQL	0.051	0.049	0.050	0.045	0.039
				NC/LA	LGT	BIN	0.052	0.053	0.055	0.047	0.042
				NC/LA	LGT	EQL	0.052	0.046	0.052	0.043	0.040
				NC/LA	NON	BIN	0.053	0.055	0.049	0.051	0.041
				NC/LA	NON	EQL	0.050	0.048	0.047	0.045	0.037
				NC/LA	NON	IPC	0.049	0.050	0.046	0.046	0.038
				HA/SE	FTB	BIN	0.052	0.054	0.052	0.051	0.040
				HA/SE	FTB	EQL	0.049	0.051	0.050	0.045	0.036
				HA/SE	LGT	BIN	0.052	0.053	0.054	0.049	0.039
				HA/SE	LGT	EQL	0.050	0.051	0.049	0.044	0.036
				HA/SE	NON	BIN	0.054	0.054	0.053	0.052	0.040
				HA/SE	NON	EQL	0.048	0.052	0.050	0.044	0.037
				HA/SE	NON	IPC	0.048	0.051	0.050	0.045	0.035
MALLARD	2:5	12	6	LAID	NON	EQL	0.049	0.052	0.051	0.042	0.040
				NC/LA	FBT	BIN	0.051	0.052	0.053	0.048	0.042
				NC/LA	FBT	EQL	0.049	0.050	0.049	0.043	0.038
				NC/LA	LGT	BIN	0.051	0.052	0.051	0.044	0.040
				NC/LA	LGT	EQL	0.050	0.053	0.052	0.043	0.040
				NC/LA	NON	BIN	0.052	0.051	0.052	0.045	0.038
				NC/LA	NON	EQL	0.048	0.049	0.047	0.044	0.035
				NC/LA	NON	IPC	0.049	0.049	0.049	0.043	0.037
				HA/SE	FTB	BIN	0.052	0.052	0.053	0.043	0.039
				HA/SE	FTB	EQL	0.050	0.046	0.047	0.039	0.032
				HA/SE	LGT	BIN	0.052	0.051	0.053	0.044	0.037
				HA/SE	LGT	EQL	0.050	0.047	0.047	0.039	0.032
				HA/SE	NON	BIN	0.051	0.052	0.053	0.043	0.039
				HA/SE	NON	EQL	0.048	0.046	0.047	0.040	0.032
				HA/SE	NON	IPC	0.049	0.047	0.046	0.039	0.033

VAR - variable analyzed

LAID - number of eggs laid

NC/LA - proportion of non-cracked eggs over eggs laid

HA/SE - proportion of eggs hatching over eggs set

HA/LA - estimated proportion of eggs hatching over eggs laid

NOHA - estimated number of eggs which hatch

TRANS. - transformation

FTB - Freeman-Tukey Binomial transformation

LGT - logistic transformation

NON - untransformed

WT. - weighting scheme

EQL - equal weighting

BIN - weight by denominator

IPC - estimated intrapen correlation weighting

Table 9: Results of testing partial null hypothesis for nominal significance level (Table entries show probability of rejecting highest dose with no treatment effect.)

SPECIES	CAGE	WEEKS	PENS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	BASN	EBAR
BOBWHITE	1:1	8	16	LAID	2	NON	EQL	0.042	0.049	0.048	0.136	0.043
			16	LAID	3	NON	EQL	0.022	0.021	0.029	0.112	0.028
				LAID	5	NON	EQL	0.041	0.041	0.045	0.250	0.043
				NC/LA	2	FTB	BIN	0.018	0.018	0.016	0.023	0.014
				NC/LA	2	FTB	EQL	0.023	0.022	0.019	0.029	0.013
				NC/LA	2	LGT	BIN	0.057	0.057	0.058	0.063	0.056
				NC/LA	2	LGT	EQL	0.050	0.050	0.050	0.055	0.046
				NC/LA	2	NON	BIN	0.004	0.004	0.003	0.012	0.001
				NC/LA	2	NON	EQL	0.006	0.006	0.005	0.024	0.004
				NC/LA	2	NON	IPC	0.005	0.005	0.003	0.015	0.003
				NC/LA	3	FTB	BIN	0.012	0.012	0.012	0.194	0.012
				NC/LA	3	FTB	EQL	0.015	0.015	0.014	0.180	0.015
				NC/LA	3	LGT	BIN	0.055	0.055	0.055	0.274	0.055
				NC/LA	3	LGT	EQL	0.043	0.043	0.043	0.252	0.043
				NC/LA	3	NON	BIN	0.002	0.002	0.002	0.131	0.002
				NC/LA	3	NON	EQL	0.002	0.002	0.002	0.133	0.002
				NC/LA	3	NON	IPC	0.001	0.001	0.001	0.119	0.001
				NC/LA	5	FTB	BIN	0.008	0.008	0.008	0.121	0.008
				NC/LA	5	FTB	EQL	0.010	0.010	0.010	0.089	0.010
				NC/LA	5	LGT	BIN	0.058	0.058	0.058	0.222	0.058
				NC/LA	5	LGT	EQL	0.049	0.049	0.048	0.188	0.049
				NC/LA	5	NON	BIN	0.001	0.001	0.001	0.070	0.001
				NC/LA	5	NON	EQL	0.001	0.001	0.001	0.049	0.001
				NC/LA	5	NON	IPC	0.001	0.001	0.001	0.042	0.001
				HA/SE	2	FTB	BIN	0.054	0.058	0.056	0.201	0.049
				HA/SE	2	FTB	EQL	0.042	0.043	0.038	0.191	0.033
				HA/SE	2	LGT	BIN	0.062	0.066	0.064	0.213	0.064
				HA/SE	2	LGT	EQL	0.046	0.047	0.044	0.203	0.038
				HA/SE	2	NON	BIN	0.048	0.052	0.047	0.180	0.042
				HA/SE	2	NON	EQL	0.038	0.040	0.034	0.176	0.030
				HA/SE	2	NON	IPC	0.037	0.038	0.034	0.176	0.027
				HA/SE	3	FTB	BIN	0.032	0.032	0.039	0.240	0.038
				HA/SE	3	FTB	EQL	0.026	0.027	0.029	0.217	0.029
				HA/SE	3	LGT	BIN	0.044	0.044	0.050	0.254	0.049
				HA/SE	3	LGT	EQL	0.034	0.033	0.037	0.234	0.037
				HA/SE	3	NON	BIN	0.024	0.024	0.030	0.224	0.029
				HA/SE	3	NON	EQL	0.022	0.022	0.024	0.203	0.024
				HA/SE	3	NON	IPC	0.020	0.020	0.021	0.209	0.021
				HA/SE	5	FTB	BIN	0.050	0.050	0.050	0.248	0.051
				HA/SE	5	FTB	EQL	0.039	0.039	0.039	0.224	0.039
				HA/SE	5	LGT	BIN	0.069	0.069	0.070	0.279	0.070
				HA/SE	5	LGT	EQL	0.049	0.049	0.049	0.255	0.049
				HA/SE	5	NON	BIN	0.038	0.038	0.037	0.222	0.038
				HA/SE	5	NON	EQL	0.029	0.029	0.029	0.205	0.029
				HA/SE	5	NON	IPC	0.027	0.027	0.027	0.198	0.027

Table 9 continued

SPECIES	CAGE	WEEKS	PENS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	BASN	EBAR
BOBWHITE	1:1	12	16	LAID	2	NON	EQL	0.042	0.049	0.048	0.150	0.043
				LAID	3	NON	EQL	0.022	0.020	0.030	0.124	0.027
				LAID	5	NON	EQL	0.035	0.035	0.040	0.253	0.039
				NC/LA	2	FTB	BIN	0.051	0.052	0.049	0.137	0.041
				NC/LA	2	FTB	EQL	0.043	0.044	0.040	0.131	0.035
				NC/LA	2	LGT	BIN	0.060	0.061	0.062	0.160	0.059
				NC/LA	2	LGT	EQL	0.056	0.056	0.054	0.160	0.049
				NC/LA	2	NON	BIN	0.036	0.036	0.033	0.119	0.030
				NC/LA	2	NON	EQL	0.032	0.032	0.029	0.115	0.022
				NC/LA	2	NON	IPC	0.032	0.031	0.029	0.111	0.024
				NC/LA	3	FTB	BIN	0.035	0.035	0.035	0.259	0.036
				NC/LA	3	FTB	EQL	0.026	0.026	0.026	0.250	0.026
				NC/LA	3	LGT	BIN	0.054	0.055	0.054	0.288	0.054
				NC/LA	3	LGT	EQL	0.041	0.041	0.042	0.280	0.042
				NC/LA	3	NON	BIN	0.022	0.022	0.023	0.237	0.023
				NC/LA	3	NON	EQL	0.017	0.017	0.017	0.221	0.017
				NC/LA	3	NON	IPC	0.016	0.016	0.017	0.223	0.017
				NC/LA	5	FTB	BIN	0.027	0.027	0.027	0.142	0.027
				NC/LA	5	FTB	EQL	0.023	0.023	0.023	0.127	0.023
				NC/LA	5	LGT	BIN	0.055	0.055	0.054	0.194	0.055
				NC/LA	5	LGT	EQL	0.046	0.046	0.045	0.187	0.046
				NC/LA	5	NON	BIN	0.015	0.015	0.015	0.111	0.015
				NC/LA	5	NON	EQL	0.012	0.012	0.012	0.093	0.012
				NC/LA	5	NON	IPC	0.011	0.011	0.011	0.092	0.011
				HA/SE	2	FTB	BIN	0.052	0.059	0.054	0.199	0.053
				HA/SE	2	FTB	EQL	0.038	0.043	0.038	0.178	0.036
				HA/SE	2	LGT	BIN	0.060	0.067	0.062	0.213	0.059
				HA/SE	2	LGT	EQL	0.040	0.045	0.039	0.188	0.039
				HA/SE	2	NON	BIN	0.048	0.054	0.049	0.187	0.046
				HA/SE	2	NON	EQL	0.036	0.040	0.037	0.174	0.033
				HA/SE	2	NON	IPC	0.034	0.039	0.036	0.172	0.033
				HA/SE	3	FTB	BIN	0.029	0.028	0.035	0.190	0.034
				HA/SE	3	FTB	EQL	0.023	0.023	0.027	0.183	0.026
				HA/SE	3	LGT	BIN	0.038	0.038	0.045	0.199	0.044
				HA/SE	3	LGT	EQL	0.028	0.027	0.033	0.195	0.031
				HA/SE	3	NON	BIN	0.022	0.024	0.029	0.179	0.028
				HA/SE	3	NON	EQL	0.019	0.020	0.023	0.172	0.021
				HA/SE	3	NON	IPC	0.020	0.020	0.023	0.173	0.022
				HA/SE	5	FTB	BIN	0.048	0.048	0.048	0.267	0.050
				HA/SE	5	FTB	EQL	0.038	0.038	0.039	0.252	0.039
				HA/SE	5	LGT	BIN	0.061	0.061	0.062	0.291	0.063
				HA/SE	5	LGT	EQL	0.046	0.047	0.047	0.272	0.048
				HA/SE	5	NON	BIN	0.039	0.039	0.040	0.251	0.040
				HA/SE	5	NON	EQL	0.032	0.032	0.034	0.244	0.034
				HA/SE	5	NON	IPC	0.033	0.033	0.034	0.243	0.034

Table 9 continued

SPECIES	CAGE	WEEKS	PENS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	BASN	EBAR
BOBWHITE	1:2	8	14	LAID	2	NON	EQL	0.042	0.047	0.047	0.146	0.040
				LAID	3	NON	EQL	0.024	0.023	0.028	0.121	0.027
				LAID	5	NON	EQL	0.042	0.042	0.043	0.255	0.043
				NC/LA	2	FTB	BIN	0.053	0.054	0.053	0.171	0.049
				NC/LA	2	FTB	EQL	0.045	0.045	0.043	0.162	0.040
				NC/LA	2	LGT	BIN	0.069	0.067	0.069	0.200	0.065
				NC/LA	2	LGT	EQL	0.057	0.058	0.055	0.187	0.050
				NC/LA	2	NON	BIN	0.041	0.041	0.038	0.151	0.035
				NC/LA	2	NON	EQL	0.035	0.035	0.034	0.152	0.027
				NC/LA	2	NON	IPC	0.035	0.036	0.031	0.147	0.027
				NC/LA	3	FTB	BIN	0.038	0.037	0.039	0.262	0.039
				NC/LA	3	FTB	EQL	0.028	0.028	0.029	0.251	0.029
				NC/LA	3	LGT	BIN	0.053	0.053	0.054	0.292	0.054
				NC/LA	3	LGT	EQL	0.044	0.044	0.045	0.281	0.045
				NC/LA	3	NON	BIN	0.024	0.024	0.025	0.241	0.025
				NC/LA	3	NON	EQL	0.016	0.016	0.017	0.229	0.017
				NC/LA	3	NON	IPC	0.016	0.016	0.017	0.233	0.017
				NC/LA	5	FTB	BIN	0.039	0.039	0.039	0.184	0.039
				NC/LA	5	FTB	EQL	0.035	0.035	0.035	0.163	0.035
				NC/LA	5	LGT	BIN	0.064	0.065	0.064	0.234	0.065
				NC/LA	5	LGT	EQL	0.056	0.056	0.056	0.213	0.056
				NC/LA	5	NON	BIN	0.021	0.021	0.021	0.149	0.021
				NC/LA	5	NON	EQL	0.016	0.016	0.016	0.131	0.016
				NC/LA	5	NON	IPC	0.016	0.016	0.016	0.131	0.016
				HA/SE	2	FTB	BIN	0.055	0.063	0.057	0.187	0.057
				HA/SE	2	FTB	EQL	0.042	0.047	0.043	0.167	0.041
				HA/SE	2	LGT	BIN	0.052	0.064	0.058	0.164	0.059
				HA/SE	2	LGT	EQL	0.038	0.048	0.043	0.152	0.044
				HA/SE	2	NON	BIN	0.053	0.059	0.055	0.187	0.053
				HA/SE	2	NON	EQL	0.040	0.045	0.042	0.168	0.038
				HA/SE	2	NON	IPC	0.042	0.045	0.042	0.174	0.039
				HA/SE	3	FTB	BIN	0.027	0.028	0.037	0.180	0.035
				HA/SE	3	FTB	EQL	0.019	0.019	0.024	0.168	0.023
				HA/SE	3	LGT	BIN	0.025	0.024	0.034	0.155	0.032
				HA/SE	3	LGT	EQL	0.018	0.018	0.024	0.152	0.023
				HA/SE	3	NON	BIN	0.027	0.027	0.036	0.184	0.035
				HA/SE	3	NON	EQL	0.017	0.017	0.022	0.174	0.021
				HA/SE	3	NON	IPC	0.018	0.017	0.022	0.176	0.021
				HA/SE	5	FTB	BIN	0.052	0.053	0.055	0.268	0.054
				HA/SE	5	FTB	EQL	0.038	0.038	0.040	0.263	0.039
				HA/SE	5	LGT	BIN	0.050	0.049	0.055	0.267	0.054
				HA/SE	5	LGT	EQL	0.038	0.038	0.040	0.259	0.039
				HA/SE	5	NON	BIN	0.051	0.051	0.053	0.258	0.052
				HA/SE	5	NON	EQL	0.039	0.039	0.040	0.251	0.040
				HA/SE	5	NON	IPC	0.037	0.037	0.037	0.251	0.038

Table 9 continued

SPECIES	CAGE	WEEKS	PENS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	BASN	EBAR
BOBWHITE	1:2	12	14	LAID	2	NON	EQL	0.039	0.043	0.042	0.154	0.038
				LAID	3	NON	EQL	0.024	0.023	0.030	0.150	0.029
				LAID	5	NON	EQL	0.040	0.039	0.042	0.274	0.043
				NC/LA	2	FTB	BIN	0.045	0.046	0.043	0.154	0.036
				NC/LA	2	FTB	EQL	0.041	0.041	0.038	0.147	0.032
				NC/LA	2	LGT	BIN	0.058	0.059	0.058	0.186	0.053
				NC/LA	2	LGT	EQL	0.050	0.050	0.050	0.178	0.042
				NC/LA	2	NON	BIN	0.036	0.036	0.031	0.140	0.027
				NC/LA	2	NON	EQL	0.034	0.034	0.029	0.137	0.024
				NC/LA	2	NON	IPC	0.033	0.034	0.030	0.137	0.023
				NC/LA	3	FTB	BIN	0.033	0.033	0.033	0.259	0.033
				NC/LA	3	FTB	EQL	0.028	0.028	0.028	0.252	0.028
				NC/LA	3	LGT	BIN	0.054	0.053	0.055	0.300	0.055
				NC/LA	3	LGT	EQL	0.045	0.045	0.046	0.294	0.046
				NC/LA	3	NON	BIN	0.020	0.020	0.021	0.234	0.021
				NC/LA	3	NON	EQL	0.017	0.017	0.018	0.223	0.017
				NC/LA	3	NON	IPC	0.017	0.017	0.017	0.224	0.017
				NC/LA	5	FTB	BIN	0.030	0.030	0.030	0.172	0.029
				NC/LA	5	FTB	EQL	0.025	0.025	0.025	0.156	0.025
				NC/LA	5	LGT	BIN	0.056	0.056	0.056	0.227	0.056
				NC/LA	5	LGT	EQL	0.054	0.054	0.054	0.213	0.054
				NC/LA	5	NON	BIN	0.014	0.014	0.014	0.141	0.014
				NC/LA	5	NON	EQL	0.014	0.014	0.014	0.123	0.014
				NC/LA	5	NON	IPC	0.013	0.013	0.013	0.121	0.013
				HA/SE	2	FTB	BIN	0.050	0.057	0.052	0.180	0.049
				HA/SE	2	FTB	EQL	0.042	0.045	0.042	0.167	0.038
				HA/SE	2	LGT	BIN	0.045	0.054	0.049	0.158	0.049
				HA/SE	2	LGT	EQL	0.036	0.041	0.039	0.150	0.037
				HA/SE	2	NON	BIN	0.049	0.053	0.051	0.181	0.046
				HA/SE	2	NON	EQL	0.041	0.044	0.042	0.175	0.037
				HA/SE	2	NON	IPC	0.041	0.044	0.043	0.175	0.037
				HA/SE	3	FTB	BIN	0.025	0.025	0.031	0.176	0.030
				HA/SE	3	FTB	EQL	0.022	0.022	0.027	0.170	0.026
				HA/SE	3	LGT	BIN	0.020	0.019	0.028	0.154	0.026
				HA/SE	3	LGT	EQL	0.020	0.018	0.026	0.147	0.022
				HA/SE	3	NON	BIN	0.025	0.024	0.031	0.180	0.030
				HA/SE	3	NON	EQL	0.020	0.020	0.025	0.178	0.022
				HA/SE	3	NON	IPC	0.020	0.020	0.025	0.179	0.023
				HA/SE	5	FTB	BIN	0.051	0.050	0.053	0.269	0.052
				HA/SE	5	FTB	EQL	0.043	0.044	0.046	0.263	0.045
				HA/SE	5	LGT	BIN	0.045	0.044	0.050	0.268	0.049
				HA/SE	5	LGT	EQL	0.040	0.040	0.044	0.268	0.043
				HA/SE	5	NON	BIN	0.045	0.045	0.047	0.258	0.046
				HA/SE	5	NON	EQL	0.039	0.039	0.040	0.250	0.040
				HA/SE	5	NON	IPC	0.039	0.039	0.040	0.250	0.039

Table 9 continued

SPECIES	CAGE	WEEKS	PENS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	BASN	EBAR
MALLARD	1:1	8	16	LAID	2	NON	EQL	0.048	0.050	0.049	0.207	0.043
				LAID	3	NON	EQL	0.034	0.034	0.040	0.232	0.039
				LAID	5	NON	EQL	0.059	0.059	0.060	0.231	0.059
				NC/LA	2	FTB	BIN	0.013	0.013	0.010	0.001	0.009
				NC/LA	2	FTB	EQL	0.015	0.015	0.012	0.001	0.009
				NC/LA	2	LGT	BIN	0.059	0.060	0.058	0.009	0.051
				NC/LA	2	LGT	EQL	0.055	0.055	0.055	0.010	0.050
				NC/LA	2	NON	BIN	0.000	0.000	0.000	0.000	0.000
				NC/LA	2	NON	EQL	0.000	0.000	0.000	0.000	0.000
				NC/LA	2	NON	IPC	0.000	0.000	0.000	0.000	0.000
				NC/LA	3	FTB	BIN	0.003	0.003	0.003	0.085	0.003
				NC/LA	3	FTB	EQL	0.004	0.004	0.004	0.074	0.004
				NC/LA	3	LGT	BIN	0.050	0.050	0.049	0.202	0.050
				NC/LA	3	LGT	EQL	0.047	0.047	0.047	0.194	0.047
				NC/LA	3	NON	BIN	0.000	0.000	0.000	0.030	0.000
				NC/LA	3	NON	EQL	0.000	0.000	0.000	0.030	0.000
				NC/LA	3	NON	IPC	0.000	0.000	0.000	0.028	0.000
				NC/LA	5	FTB	BIN	0.002	0.002	0.002	0.033	0.002
				NC/LA	5	FTB	EQL	0.003	0.003	0.003	0.023	0.003
				NC/LA	5	LGT	BIN	0.059	0.059	0.059	0.144	0.059
				NC/LA	5	LGT	EQL	0.055	0.055	0.055	0.136	0.055
				NC/LA	5	NON	BIN	0.000	0.000	0.000	0.007	0.000
				NC/LA	5	NON	EQL	0.000	0.000	0.000	0.002	0.000
				NC/LA	5	NON	IPC	0.000	0.000	0.000	0.002	0.000
				HA/SE	2	FTB	BIN	0.042	0.045	0.044	0.193	0.040
				HA/SE	2	FTB	EQL	0.041	0.044	0.039	0.194	0.037
				HA/SE	2	LGT	BIN	0.045	0.050	0.047	0.196	0.043
				HA/SE	2	LGT	EQL	0.043	0.046	0.045	0.190	0.039
				HA/SE	2	NON	BIN	0.040	0.041	0.043	0.188	0.037
				HA/SE	2	NON	EQL	0.037	0.041	0.039	0.191	0.037
				HA/SE	2	NON	IPC	0.037	0.041	0.039	0.191	0.035
				HA/SE	3	FTB	BIN	0.029	0.029	0.033	0.207	0.033
				HA/SE	3	FTB	EQL	0.025	0.025	0.030	0.208	0.029
				HA/SE	3	LGT	BIN	0.032	0.032	0.037	0.213	0.036
				HA/SE	3	LGT	EQL	0.030	0.030	0.035	0.208	0.034
				HA/SE	3	NON	BIN	0.025	0.025	0.029	0.201	0.027
				HA/SE	3	NON	EQL	0.023	0.023	0.027	0.200	0.025
				HA/SE	3	NON	IPC	0.023	0.024	0.027	0.200	0.026
				HA/SE	5	FTB	BIN	0.043	0.043	0.042	0.244	0.043
				HA/SE	5	FTB	EQL	0.045	0.045	0.043	0.243	0.044
				HA/SE	5	LGT	BIN	0.052	0.052	0.052	0.266	0.052
				HA/SE	5	LGT	EQL	0.048	0.048	0.048	0.261	0.048
				HA/SE	5	NON	BIN	0.038	0.039	0.038	0.235	0.038
				HA/SE	5	NON	EQL	0.038	0.038	0.037	0.226	0.038
				HA/SE	5	NON	IPC	0.038	0.038	0.037	0.226	0.039

Table 9 continued

SPECIES	CAGE	WEEKS	PENS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	BASN	EBAR
MALLARD	2:5	8	6	LAID	2	NON	EQL	0.039	0.042	0.043	0.158	0.039
				LAID	3	NON	EQL	0.024	0.024	0.031	0.148	0.029
				LAID	5	NON	EQL	0.043	0.043	0.045	0.255	0.044
				NC/LA	2	FTB	BIN	0.027	0.028	0.025	0.105	0.021
				NC/LA	2	FTB	EQL	0.025	0.025	0.022	0.102	0.016
				NC/LA	2	LGT	BIN	0.049	0.050	0.048	0.157	0.044
				NC/LA	2	LGT	EQL	0.047	0.047	0.046	0.163	0.043
				NC/LA	2	NON	BIN	0.013	0.013	0.011	0.074	0.009
				NC/LA	2	NON	EQL	0.009	0.010	0.009	0.070	0.007
				NC/LA	2	NON	IPC	0.010	0.010	0.008	0.071	0.007
				NC/LA	3	FTB	BIN	0.018	0.018	0.018	0.233	0.018
				NC/LA	3	FTB	EQL	0.016	0.016	0.017	0.227	0.016
				NC/LA	3	LGT	BIN	0.050	0.049	0.051	0.294	0.050
				NC/LA	3	LGT	EQL	0.049	0.049	0.050	0.294	0.049
				NC/LA	3	NON	BIN	0.004	0.005	0.006	0.179	0.005
				NC/LA	3	NON	EQL	0.004	0.004	0.005	0.172	0.005
				NC/LA	3	NON	IPC	0.005	0.005	0.005	0.169	0.005
				NC/LA	5	FTB	BIN	0.013	0.013	0.013	0.131	0.013
				NC/LA	5	FTB	EQL	0.012	0.012	0.012	0.112	0.012
				NC/LA	5	LGT	BIN	0.058	0.058	0.058	0.236	0.058
				NC/LA	5	LGT	EQL	0.054	0.054	0.055	0.235	0.054
				NC/LA	5	NON	BIN	0.001	0.001	0.001	0.077	0.001
				NC/LA	5	NON	EQL	0.002	0.002	0.002	0.057	0.002
				NC/LA	5	NON	IPC	0.001	0.001	0.001	0.057	0.001
				HA/SE	2	FTB	BIN	0.049	0.052	0.051	0.200	0.041
				HA/SE	2	FTB	EQL	0.046	0.048	0.046	0.195	0.040
				HA/SE	2	LGT	BIN	0.050	0.053	0.052	0.206	0.042
				HA/SE	2	LGT	EQL	0.049	0.051	0.049	0.196	0.041
				HA/SE	2	NON	BIN	0.048	0.049	0.049	0.198	0.039
				HA/SE	2	NON	EQL	0.044	0.047	0.045	0.192	0.039
				HA/SE	2	NON	IPC	0.044	0.047	0.045	0.193	0.038
				HA/SE	3	FTB	BIN	0.031	0.032	0.037	0.191	0.035
				HA/SE	3	FTB	EQL	0.029	0.029	0.034	0.193	0.032
				HA/SE	3	LGT	BIN	0.033	0.033	0.038	0.195	0.036
				HA/SE	3	LGT	EQL	0.032	0.032	0.037	0.195	0.035
				HA/SE	3	NON	BIN	0.029	0.031	0.036	0.189	0.033
				HA/SE	3	NON	EQL	0.027	0.027	0.033	0.191	0.031
				HA/SE	3	NON	IPC	0.027	0.027	0.032	0.190	0.030
				HA/SE	5	FTB	BIN	0.053	0.053	0.054	0.249	0.054
				HA/SE	5	FTB	EQL	0.047	0.047	0.048	0.237	0.048
				HA/SE	5	LGT	BIN	0.053	0.052	0.054	0.251	0.053
				HA/SE	5	LGT	EQL	0.047	0.047	0.048	0.238	0.047
				HA/SE	5	NON	BIN	0.052	0.052	0.054	0.247	0.053
				HA/SE	5	NON	EQL	0.048	0.048	0.049	0.237	0.047
				HA/SE	5	NON	IPC	0.049	0.049	0.049	0.238	0.048

Table 9 continued

SPECIES	CAGE	WEEKS	PENS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	BASN	EBAR
MALLARD	2:5	12	6	LAID	2	NON	EQL	0.038	0.042	0.040	0.147	0.032
				LAID	3	NON	EQL	0.023	0.023	0.028	0.139	0.026
				LAID	5	NON	EQL	0.038	0.038	0.040	0.255	0.039
				NC/LA	2	FTB	BIN	0.028	0.028	0.026	0.034	0.021
				NC/LA	2	FTB	EQL	0.026	0.026	0.023	0.032	0.016
				NC/LA	2	LGT	BIN	0.055	0.056	0.054	0.087	0.051
				NC/LA	2	LGT	EQL	0.052	0.052	0.050	0.082	0.045
				NC/LA	2	NON	BIN	0.008	0.008	0.006	0.017	0.005
				NC/LA	2	NON	EQL	0.006	0.006	0.004	0.015	0.003
				NC/LA	2	NON	IPC	0.006	0.006	0.005	0.016	0.004
				NC/LA	3	FTB	BIN	0.015	0.015	0.015	0.175	0.015
				NC/LA	3	FTB	EQL	0.013	0.013	0.013	0.160	0.013
				NC/LA	3	LGT	BIN	0.052	0.052	0.053	0.253	0.051
				NC/LA	3	LGT	EQL	0.049	0.049	0.050	0.250	0.050
				NC/LA	3	NON	BIN	0.003	0.003	0.003	0.113	0.003
				NC/LA	3	NON	EQL	0.002	0.002	0.002	0.103	0.002
				NC/LA	3	NON	IPC	0.002	0.002	0.002	0.100	0.002
				NC/LA	5	FTB	BIN	0.009	0.009	0.009	0.076	0.009
				NC/LA	5	FTB	EQL	0.007	0.007	0.007	0.056	0.007
				NC/LA	5	LGT	BIN	0.056	0.056	0.056	0.186	0.056
				NC/LA	5	LGT	EQL	0.052	0.052	0.052	0.176	0.052
				NC/LA	5	NON	BIN	0.000	0.000	0.001	0.031	0.000
				NC/LA	5	NON	EQL	0.001	0.001	0.001	0.012	0.001
				NC/LA	5	NON	IPC	0.000	0.000	0.000	0.014	0.000
				HA/SE	2	FTB	BIN	0.047	0.050	0.050	0.175	0.047
				HA/SE	2	FTB	EQL	0.046	0.050	0.049	0.174	0.045
				HA/SE	2	LGT	BIN	0.046	0.050	0.051	0.174	0.046
				HA/SE	2	LGT	EQL	0.045	0.049	0.048	0.175	0.043
				HA/SE	2	NON	BIN	0.048	0.051	0.051	0.177	0.049
				HA/SE	2	NON	EQL	0.047	0.050	0.050	0.176	0.045
				HA/SE	2	NON	IPC	0.046	0.049	0.050	0.177	0.043
				HA/SE	3	FTB	BIN	0.032	0.032	0.037	0.161	0.036
				HA/SE	3	FTB	EQL	0.029	0.029	0.034	0.160	0.032
				HA/SE	3	LGT	BIN	0.031	0.032	0.036	0.158	0.035
				HA/SE	3	LGT	EQL	0.029	0.028	0.034	0.161	0.031
				HA/SE	3	NON	BIN	0.032	0.032	0.038	0.162	0.036
				HA/SE	3	NON	EQL	0.030	0.030	0.034	0.162	0.033
				HA/SE	3	NON	IPC	0.030	0.029	0.034	0.163	0.032
				HA/SE	5	FTB	BIN	0.046	0.046	0.047	0.251	0.047
				HA/SE	5	FTB	EQL	0.041	0.041	0.042	0.253	0.042
				HA/SE	5	LGT	BIN	0.043	0.043	0.043	0.245	0.043
				HA/SE	5	LGT	EQL	0.038	0.038	0.039	0.245	0.039
				HA/SE	5	NON	BIN	0.047	0.047	0.048	0.257	0.048
				HA/SE	5	NON	EQL	0.043	0.043	0.045	0.261	0.044
				HA/SE	5	NON	IPC	0.044	0.044	0.045	0.259	0.045

Table 10: Estimated number of pens required at each treatment level to provide 80% power for identifying lowest dose which causes a 20 % reduction.

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
BOBWHITE	1:1	8	LAID	2	NON	EQL	68.7	70.8	71.2	63.9
			LAID	3	NON	EQL	69.1	59.7	71.2	66.6
			LAID	4	NON	EQL	65.0	61.0	65.4	69.9
			LAID	5	NON	EQL	63.7	65.5	66.3	60.8
			LAID	6	NON	EQL	62.4	62.1	64.1	68.4
			LAID	7	NON	EQL	62.9	62.9	64.0	63.5
			LAID	8	NON	EQL	84.0	85.6	73.5	75.1
			NC/LA	2	NON	EQL	.	9.7	.	.
			NC/LA	3	NON	EQL	11.3	.	11.4	.
			NC/LA	4	NON	EQL	.	.	.	11.7
			NC/LA	5	NON	EQL	.	11.3	.	12.4
			NC/LA	6	FTB	EQL	.	.	13.2	12.1
			NC/LA	6	LGT	BIN	11.7	11.7	11.7	11.7
			NC/LA	6	LGT	EQL	11.7	11.7	11.7	11.7
			NC/LA	6	NON	BIN	.	.	14.1	13.3
			NC/LA	6	NON	EQL	11.8	11.8	11.3	11.6
			NC/LA	6	NON	IPC	11.7	.	10.2	11.7
			NC/LA	7	NON	BIN	10.4	10.4	10.4	10.4
			NC/LA	7	NON	EQL	10.3	10.3	10.3	10.3
			NC/LA	7	NON	IPC	13.1	13.1	13.1	13.1
			NC/LA	8	FTB	BIN	.	11.6	.	.
			NC/LA	8	FTB	EQL	12.6	11.3	.	.
			NC/LA	8	NON	BIN	12.3	10.7	11.7	12.1
			NC/LA	8	NON	EQL	10.4	10.6	9.6	9.8
			NC/LA	8	NON	IPC	13.4	10.9	.	.
			HA/SE	2	FTB	BIN	21.1	23.6	22.9	19.4
			HA/SE	2	FTB	EQL	21.3	23.7	23.1	20.4
			HA/SE	2	LGT	BIN	23.0	25.7	25.0	20.6
			HA/SE	2	LGT	EQL	22.5	25.2	24.5	21.3
			HA/SE	2	NON	BIN	20.5	22.9	22.3	19.2
			HA/SE	2	NON	EQL	21.3	23.7	23.1	20.7
			HA/SE	2	NON	IPC	20.6	22.9	22.4	19.9
			HA/SE	3	FTB	BIN	21.5	17.1	22.3	19.3
			HA/SE	3	FTB	EQL	21.8	17.3	23.0	20.5
			HA/SE	3	LGT	BIN	22.6	17.8	23.4	20.1
			HA/SE	3	LGT	EQL	22.6	18.0	23.9	21.2
			HA/SE	3	NON	BIN	21.4	17.1	22.2	19.4
			HA/SE	3	NON	EQL	22.0	17.8	23.1	21.1
			HA/SE	3	NON	IPC	21.3	17.2	22.4	20.4
			HA/SE	4	FTB	BIN	22.6	20.2	22.1	23.6
			HA/SE	4	FTB	EQL	22.7	20.3	22.7	25.0
			HA/SE	4	LGT	BIN	22.9	20.6	22.6	24.1
			HA/SE	4	LGT	EQL	22.8	20.4	22.9	25.3
			HA/SE	4	NON	BIN	22.8	20.5	22.3	24.0
			HA/SE	4	NON	EQL	23.3	20.9	23.4	25.7
			HA/SE	4	NON	IPC	22.6	20.3	22.6	24.9

Table 10 continued

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
BOBWHITE	1:1	8	HA/SE	5	FTB	BIN	21.9	21.9	23.5	20.3
			HA/SE	5	FTB	EQL	22.2	22.2	23.7	21.1
			HA/SE	5	LGT	BIN	22.2	22.0	23.6	19.8
			HA/SE	5	LGT	EQL	22.1	22.0	23.4	20.6
			HA/SE	5	NON	BIN	22.6	22.5	24.1	21.4
			HA/SE	5	NON	EQL	23.2	23.3	24.8	22.4
			HA/SE	5	NON	IPC	22.5	22.4	24.0	21.6
			HA/SE	6	FTB	BIN	23.9	23.4	24.0	25.9
			HA/SE	6	FTB	EQL	24.2	23.7	24.5	26.8
			HA/SE	6	LGT	BIN	23.6	23.0	23.6	25.3
			HA/SE	6	LGT	EQL	23.4	23.1	23.8	26.0
			HA/SE	6	NON	BIN	24.8	24.4	25.0	27.0
			HA/SE	6	NON	EQL	25.5	25.1	25.9	28.5
			HA/SE	6	NON	IPC	24.7	24.3	25.0	27.6
			HA/SE	7	FTB	BIN	22.5	22.5	22.6	22.5
			HA/SE	7	FTB	EQL	22.6	22.6	22.8	22.6
			HA/SE	7	LGT	BIN	21.8	21.9	21.9	21.8
			HA/SE	7	LGT	EQL	21.9	21.9	22.0	21.9
			HA/SE	7	NON	BIN	23.7	23.7	23.8	23.6
			HA/SE	7	NON	EQL	24.3	24.3	24.4	24.3
			HA/SE	7	NON	IPC	23.5	23.5	23.6	23.5
			HA/SE	8	FTB	BIN	33.7	35.3	27.7	28.4
			HA/SE	8	FTB	EQL	33.2	34.7	27.5	28.2
			HA/SE	8	LGT	BIN	33.0	34.5	27.2	28.0
			HA/SE	8	LGT	EQL	32.1	33.4	26.8	27.5
			HA/SE	8	NON	BIN	34.8	36.5	28.6	29.4
			HA/SE	8	NON	EQL	35.1	36.7	29.0	29.8
			HA/SE	8	NON	IPC	34.2	35.7	28.2	28.9
BOBWHITE	1:1	12	LAID	2	NON	EQL	61.2	66.3	64.6	59.2
			LAID	3	NON	EQL	61.8	52.2	63.9	58.4
			LAID	4	NON	EQL	60.3	55.1	60.5	64.5
			LAID	5	NON	EQL	58.5	59.5	62.0	55.8
			LAID	6	NON	EQL	56.5	56.3	57.9	61.9
			LAID	7	NON	EQL	56.4	56.4	57.0	56.8
			LAID	8	NON	EQL	73.3	74.9	65.8	66.8
			NC/LA	2	FTB	BIN	8.8	9.7	9.6	9.0
			NC/LA	2	FTB	EQL	8.5	9.3	9.5	9.1
			NC/LA	2	LGT	BIN	9.4	10.6	10.2	9.5
			NC/LA	2	LGT	EQL	9.5	10.6	10.6	10.0
			NC/LA	2	NON	BIN	9.1	9.0	9.4	9.3
			NC/LA	2	NON	EQL	7.3	9.0	8.9	9.2
			NC/LA	2	NON	IPC	7.9	9.1	9.3	8.8
			NC/LA	3	FTB	BIN	9.9	8.4	10.4	8.9
			NC/LA	3	FTB	EQL	10.3	9.3	10.8	10.4
			NC/LA	3	LGT	BIN	10.0	9.3	10.7	10.3
			NC/LA	3	LGT	EQL	10.8	9.5	11.0	10.5
			NC/LA	3	NON	BIN	9.9	8.7	10.4	9.4
			NC/LA	3	NON	EQL	10.1	9.4	10.8	10.1

Table 10 continued

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
BOBWHITE	1:1	12	NC/LA	3	NON	IPC	9.6	8.7	10.3	10.1
			NC/LA	4	FTB	BIN	9.4	8.7	9.4	11.0
			NC/LA	4	FTB	EQL	10.7	9.5	10.7	11.5
			NC/LA	4	LGT	BIN	9.4	8.6	9.7	10.3
			NC/LA	4	LGT	EQL	10.8	9.6	10.8	11.0
			NC/LA	4	NON	BIN	9.7	9.5	10.0	11.2
			NC/LA	4	NON	EQL	10.9	9.7	10.9	11.8
			NC/LA	4	NON	IPC	10.7	9.8	10.5	11.6
			NC/LA	5	FTB	BIN	10.4	10.4	10.8	10.7
			NC/LA	5	FTB	EQL	10.1	10.3	10.7	10.4
			NC/LA	5	LGT	BIN	10.4	10.4	10.7	10.5
			NC/LA	5	LGT	EQL	10.2	10.3	10.8	10.5
			NC/LA	5	NON	BIN	10.9	10.7	11.3	11.3
			NC/LA	5	NON	EQL	10.6	10.6	11.3	11.4
			NC/LA	5	NON	IPC	10.7	10.8	11.2	11.1
			NC/LA	6	FTB	BIN	10.2	10.2	10.7	11.3
			NC/LA	6	FTB	EQL	10.1	10.0	10.4	11.9
			NC/LA	6	LGT	BIN	9.9	10.0	10.0	10.9
			NC/LA	6	LGT	EQL	9.8	9.6	9.9	11.0
			NC/LA	6	NON	BIN	11.3	11.1	11.6	12.0
			NC/LA	6	NON	EQL	11.0	10.8	11.3	12.8
			NC/LA	6	NON	IPC	11.1	11.1	11.6	12.4
			NC/LA	7	FTB	BIN	10.3	10.3	10.4	10.3
			NC/LA	7	FTB	EQL	11.0	11.0	11.1	11.0
			NC/LA	7	LGT	BIN	9.2	9.2	9.2	9.2
			NC/LA	7	LGT	EQL	9.9	9.9	10.0	9.9
			NC/LA	7	NON	BIN	11.4	11.4	11.4	11.4
			NC/LA	7	NON	EQL	12.0	12.0	12.0	12.0
			NC/LA	7	NON	IPC	11.7	11.7	11.7	11.7
			NC/LA	8	FTB	BIN	14.0	14.6	12.2	12.4
			NC/LA	8	FTB	EQL	14.5	15.0	12.4	12.8
			NC/LA	8	LGT	BIN	12.7	13.3	11.7	11.7
			NC/LA	8	LGT	EQL	13.4	13.6	11.6	11.9
			NC/LA	8	NON	BIN	15.4	16.0	12.6	13.0
			NC/LA	8	NON	EQL	16.1	16.6	13.4	13.7
			NC/LA	8	NON	IPC	15.5	16.1	13.2	13.4
			HA/SE	2	FTB	BIN	35.9	38.7	38.3	33.4
			HA/SE	2	FTB	EQL	35.3	38.6	37.6	33.5
			HA/SE	2	LGT	BIN	37.3	40.3	39.6	34.2
			HA/SE	2	LGT	EQL	36.2	40.0	38.6	34.2
			HA/SE	2	NON	BIN	35.5	38.6	37.9	33.5
			HA/SE	2	NON	EQL	35.3	38.6	37.5	33.8
			HA/SE	2	NON	IPC	34.9	38.3	37.1	33.5
			HA/SE	3	FTB	BIN	36.7	29.9	37.9	32.9
			HA/SE	3	FTB	EQL	35.6	28.9	36.8	33.1
			HA/SE	3	LGT	BIN	37.6	30.3	39.0	33.2
			HA/SE	3	LGT	EQL	36.1	29.3	37.6	33.2
			HA/SE	3	NON	BIN	36.8	30.2	37.8	33.3

Table 10 continued

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
BOBWHITE	1:1	12	HA/SE	3	NON	EQL	35.7	29.4	37.2	33.4
			HA/SE	3	NON	IPC	35.4	29.1	36.9	33.1
			HA/SE	4	FTB	BIN	36.9	33.4	36.3	39.1
			HA/SE	4	FTB	EQL	36.1	32.7	36.1	39.4
			HA/SE	4	LGT	BIN	37.1	33.5	36.7	38.9
			HA/SE	4	LGT	EQL	36.0	32.7	36.5	39.5
			HA/SE	4	NON	BIN	37.1	33.7	36.5	39.6
			HA/SE	4	NON	EQL	36.7	33.2	36.7	39.7
			HA/SE	4	NON	IPC	36.4	32.9	36.4	39.4
			HA/SE	5	FTB	BIN	36.7	36.4	38.6	33.8
			HA/SE	5	FTB	EQL	35.5	35.5	37.8	32.8
			HA/SE	5	LGT	BIN	36.7	36.6	38.6	33.1
			HA/SE	5	LGT	EQL	35.6	35.7	37.9	32.6
			HA/SE	5	NON	BIN	37.2	37.0	39.2	34.5
			HA/SE	5	NON	EQL	36.0	36.0	38.3	33.7
			HA/SE	5	NON	IPC	35.7	35.7	37.9	33.4
			HA/SE	6	FTB	BIN	37.0	36.6	37.3	40.3
			HA/SE	6	FTB	EQL	35.4	34.9	36.0	39.1
			HA/SE	6	LGT	BIN	36.7	36.2	37.0	39.5
			HA/SE	6	LGT	EQL	35.1	34.6	35.7	38.7
			HA/SE	6	NON	BIN	38.0	37.5	38.1	41.2
			HA/SE	6	NON	EQL	36.2	35.8	36.6	40.1
			HA/SE	6	NON	IPC	36.1	35.7	36.5	39.9
			HA/SE	7	FTB	BIN	36.0	36.0	36.2	36.0
			HA/SE	7	FTB	EQL	34.9	34.9	35.0	34.9
			HA/SE	7	LGT	BIN	35.2	35.2	35.4	35.2
			HA/SE	7	LGT	EQL	34.4	34.4	34.6	34.4
			HA/SE	7	NON	BIN	37.0	37.0	37.2	37.0
			HA/SE	7	NON	EQL	35.5	35.5	35.7	35.5
			HA/SE	7	NON	IPC	35.3	35.3	35.4	35.3
			HA/SE	8	FTB	BIN	35.8	39.8	28.7	33.3
			HA/SE	8	FTB	EQL	34.9	38.4	28.3	33.0
			HA/SE	8	LGT	BIN	35.0	38.8	28.4	33.0
			HA/SE	8	LGT	EQL	34.0	37.5	27.9	32.6
			HA/SE	8	NON	BIN	36.7	41.0	29.4	34.0
			HA/SE	8	NON	EQL	35.9	39.4	29.1	33.7
			HA/SE	8	NON	IPC	35.7	39.2	28.8	33.4
BOBWHITE	1:2	8	LAID	2	NON	EQL	51.7	55.6	54.8	49.2
			LAID	3	NON	EQL	52.0	44.5	53.3	49.9
			LAID	4	NON	EQL	52.8	48.4	52.7	55.9
			LAID	5	NON	EQL	51.2	51.9	53.5	48.5
			LAID	6	NON	EQL	51.7	51.8	52.8	57.1
			LAID	7	NON	EQL	49.4	49.4	49.9	49.6
			LAID	8	NON	EQL	65.2	67.0	57.2	58.0
			NC/LA	2	FTB	BIN	10.0	10.5	10.7	9.8
			NC/LA	2	FTB	EQL	10.5	11.2	11.3	10.3
			NC/LA	2	LGT	BIN	10.4	11.3	11.1	9.8
			NC/LA	2	LGT	EQL	10.9	11.7	11.6	10.2

Table 10 continued

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
BOBWHITE	1:2	8	NC/LA	2	NON	BIN	9.9	10.8	10.8	10.0
			NC/LA	2	NON	EQL	10.6	11.5	11.6	10.9
			NC/LA	2	NON	IPC	10.4	11.0	11.3	10.5
			NC/LA	3	FTB	BIN	10.5	9.0	10.6	10.1
			NC/LA	3	FTB	EQL	11.0	9.2	11.4	10.8
			NC/LA	3	LGT	BIN	10.3	8.8	10.9	10.0
			NC/LA	3	LGT	EQL	10.9	9.1	11.3	10.5
			NC/LA	3	NON	BIN	10.8	9.0	11.3	10.7
			NC/LA	3	NON	EQL	11.4	9.7	11.9	11.2
			NC/LA	3	NON	IPC	10.9	9.4	11.6	10.9
			NC/LA	4	FTB	BIN	10.7	9.8	10.6	11.3
			NC/LA	4	FTB	EQL	10.7	10.2	10.8	11.7
			NC/LA	4	LGT	BIN	9.9	9.2	10.2	10.8
			NC/LA	4	LGT	EQL	10.1	9.7	10.2	11.5
			NC/LA	4	NON	BIN	11.1	10.4	11.1	12.0
			NC/LA	4	NON	EQL	11.5	10.7	11.6	12.5
			NC/LA	4	NON	IPC	11.3	10.3	11.5	12.4
			NC/LA	5	FTB	BIN	10.4	10.3	11.1	10.2
			NC/LA	5	FTB	EQL	11.0	10.9	11.7	10.6
			NC/LA	5	LGT	BIN	9.6	9.7	10.3	9.3
			NC/LA	5	LGT	EQL	10.3	10.3	10.8	9.7
			NC/LA	5	NON	BIN	11.5	11.4	12.3	11.2
			NC/LA	5	NON	EQL	12.1	12.1	13.0	12.0
			NC/LA	5	NON	IPC	11.8	11.8	12.6	11.6
BOBWHITE	1:2	8	NC/LA	6	FTB	BIN	10.7	10.6	10.7	11.9
			NC/LA	6	FTB	EQL	11.3	11.1	11.5	12.8
			NC/LA	6	LGT	BIN	9.7	9.6	9.6	10.4
			NC/LA	6	LGT	EQL	10.5	10.3	10.5	11.3
			NC/LA	6	NON	BIN	12.0	11.8	12.0	13.7
			NC/LA	6	NON	EQL	12.8	12.7	13.1	14.7
			NC/LA	6	NON	IPC	12.3	12.2	12.5	14.1
			NC/LA	7	FTB	BIN	11.4	11.4	11.4	11.4
			NC/LA	7	FTB	EQL	11.6	11.6	11.6	11.6
			NC/LA	7	LGT	BIN	9.9	9.9	10.0	9.9
			NC/LA	7	LGT	EQL	10.2	10.2	10.2	10.2
			NC/LA	7	NON	BIN	13.1	13.1	13.1	13.1
			NC/LA	7	NON	EQL	13.3	13.3	13.3	13.3
			NC/LA	7	NON	IPC	13.0	13.0	13.1	13.0
			NC/LA	8	FTB	BIN	15.9	16.6	12.8	13.3
			NC/LA	8	FTB	EQL	16.2	16.9	13.3	13.6
			NC/LA	8	LGT	BIN	14.0	14.5	11.7	11.9
			NC/LA	8	LGT	EQL	14.3	14.8	12.1	12.4
			NC/LA	8	NON	BIN	17.9	18.8	14.4	14.8
			NC/LA	8	NON	EQL	18.3	19.2	14.9	15.3
			NC/LA	8	NON	IPC	17.8	18.6	14.5	15.0
			HA/SE	2	FTB	BIN	36.3	40.3	38.8	33.1
			HA/SE	2	FTB	EQL	35.5	38.8	37.8	33.6
			HA/SE	2	LGT	BIN	48.1	53.2	50.9	43.1

Table 10 continued

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
BOBWHITE	1:2	8	HA/SE	2	LGT	EQL	44.3	49.0	47.4	41.8
			HA/SE	2	NON	BIN	32.0	35.3	34.1	29.2
			HA/SE	2	NON	EQL	32.0	34.8	34.1	30.3
			HA/SE	2	NON	IPC	31.6	34.4	33.5	29.8
			HA/SE	3	FTB	BIN	34.9	28.9	35.8	31.9
			HA/SE	3	FTB	EQL	34.2	28.6	35.7	32.4
			HA/SE	3	LGT	BIN	45.0	38.3	46.6	41.8
			HA/SE	3	LGT	EQL	42.8	35.8	44.5	41.1
			HA/SE	3	NON	BIN	30.8	25.6	31.8	28.3
			HA/SE	3	NON	EQL	31.2	26.0	32.7	29.6
			HA/SE	3	NON	IPC	30.8	25.5	32.0	29.1
			HA/SE	4	FTB	BIN	34.2	31.4	33.9	36.5
			HA/SE	4	FTB	EQL	33.3	30.5	33.8	36.9
			HA/SE	4	LGT	BIN	43.8	40.7	43.6	46.1
			HA/SE	4	LGT	EQL	41.2	38.3	41.8	45.5
			HA/SE	4	NON	BIN	30.7	28.0	30.6	32.7
			HA/SE	4	NON	EQL	30.9	28.0	31.2	34.0
			HA/SE	4	NON	IPC	30.2	27.5	30.5	33.4
			HA/SE	5	FTB	BIN	34.2	34.4	35.9	31.6
			HA/SE	5	FTB	EQL	34.1	34.1	36.1	31.7
			HA/SE	5	LGT	BIN	43.8	44.2	46.4	40.3
			HA/SE	5	LGT	EQL	41.8	42.1	44.0	39.3
			HA/SE	5	NON	BIN	30.8	30.9	32.4	28.5
			HA/SE	5	NON	EQL	31.3	31.2	33.1	29.4
			HA/SE	5	NON	IPC	30.7	30.8	32.6	29.0
			HA/SE	6	FTB	BIN	35.9	35.4	36.2	38.5
			HA/SE	6	FTB	EQL	35.2	34.9	36.0	39.1
			HA/SE	6	LGT	BIN	45.2	44.4	46.0	48.8
			HA/SE	6	LGT	EQL	43.1	42.7	43.9	47.5
			HA/SE	6	NON	BIN	32.8	32.3	33.0	35.0
			HA/SE	6	NON	EQL	32.8	32.4	33.4	36.3
			HA/SE	6	NON	IPC	32.2	31.8	32.8	35.7
			HA/SE	7	FTB	BIN	32.6	32.6	32.7	32.6
			HA/SE	7	FTB	EQL	32.0	32.0	32.1	32.0
			HA/SE	7	LGT	BIN	41.1	41.1	41.4	41.2
			HA/SE	7	LGT	EQL	39.5	39.5	39.7	39.6
			HA/SE	7	NON	BIN	29.3	29.3	29.4	29.3
			HA/SE	7	NON	EQL	29.5	29.5	29.6	29.5
			HA/SE	7	NON	IPC	29.0	29.0	29.1	29.0
			HA/SE	8	FTB	BIN	48.3	49.7	41.4	42.1
			HA/SE	8	FTB	EQL	46.3	47.4	39.4	40.3
			HA/SE	8	LGT	BIN	58.0	59.6	51.4	51.9
			HA/SE	8	LGT	EQL	54.4	55.3	47.5	48.5
			HA/SE	8	NON	BIN	44.5	45.8	37.7	38.5
			HA/SE	8	NON	EQL	43.2	44.3	36.7	37.6
			HA/SE	8	NON	IPC	42.7	44.0	36.3	37.1

Table 10 continued

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
BOBWHITE	1:2	12	LAID	2	NON	EQL	42.8	46.8	45.3	40.5
			LAID	3	NON	EQL	42.8	36.3	44.2	40.6
			LAID	4	NON	EQL	42.4	39.3	43.2	47.0
			LAID	5	NON	EQL	40.5	40.7	42.7	37.7
			LAID	6	NON	EQL	41.5	41.2	42.7	46.3
			LAID	7	NON	EQL	39.2	39.2	39.5	39.3
			LAID	8	NON	EQL	54.2	55.5	46.8	47.8
			NC/LA	2	FTB	BIN	8.6	9.8	9.3	9.1
			NC/LA	2	FTB	EQL	8.7	9.9	9.7	9.5
			NC/LA	2	LGT	BIN	9.3	10.5	10.1	9.3
			NC/LA	2	LGT	EQL	9.1	10.7	10.3	9.6
			NC/LA	2	NON	BIN	8.8	9.7	9.5	9.3
			NC/LA	2	NON	EQL	8.6	10.1	10.0	10.0
			NC/LA	2	NON	IPC	8.7	10.1	9.8	9.8
			NC/LA	3	FTB	BIN	9.8	8.4	9.9	9.3
			NC/LA	3	FTB	EQL	10.2	8.4	10.5	10.0
			NC/LA	3	LGT	BIN	9.8	8.1	10.2	9.3
			NC/LA	3	LGT	EQL	9.8	8.4	10.4	9.8
			NC/LA	3	NON	BIN	10.3	8.6	10.4	9.7
			NC/LA	3	NON	EQL	10.7	8.9	10.9	10.3
			NC/LA	3	NON	IPC	10.6	8.6	10.8	10.2
			NC/LA	4	FTB	BIN	10.2	9.2	10.1	11.0
			NC/LA	4	FTB	EQL	10.1	9.2	10.2	11.5
			NC/LA	4	LGT	BIN	9.9	8.9	9.8	10.7
			NC/LA	4	LGT	EQL	10.0	9.1	9.8	10.8
			NC/LA	4	NON	BIN	10.9	9.6	10.5	11.6
			NC/LA	4	NON	EQL	10.9	9.9	11.0	12.0
			NC/LA	4	NON	IPC	10.7	9.8	11.0	11.8
			NC/LA	5	FTB	BIN	10.0	10.0	10.7	10.3
			NC/LA	5	FTB	EQL	10.3	10.4	10.8	9.9
			NC/LA	5	LGT	BIN	9.7	9.6	10.0	9.5
			NC/LA	5	LGT	EQL	9.8	9.9	10.2	9.1
			NC/LA	5	NON	BIN	11.1	11.2	11.8	11.0
			NC/LA	5	NON	EQL	11.1	11.2	11.8	11.1
			NC/LA	5	NON	IPC	11.1	11.0	11.7	11.0
			NC/LA	6	FTB	BIN	10.5	10.3	10.4	11.6
			NC/LA	6	FTB	EQL	10.7	10.6	10.9	12.0
			NC/LA	6	LGT	BIN	9.9	9.9	10.0	10.7
			NC/LA	6	LGT	EQL	10.1	10.0	10.3	11.2
			NC/LA	6	NON	BIN	11.5	11.3	11.6	12.9
			NC/LA	6	NON	EQL	11.9	11.7	12.0	13.4
			NC/LA	6	NON	IPC	11.6	11.5	11.8	13.3
			NC/LA	7	FTB	BIN	10.0	10.0	10.0	10.0
			NC/LA	7	FTB	EQL	10.1	10.1	10.1	10.1
			NC/LA	7	LGT	BIN	8.4	8.4	8.4	8.4
			NC/LA	7	LGT	EQL	8.1	8.1	8.1	8.1
			NC/LA	7	NON	BIN	11.8	11.8	11.8	11.8
			NC/LA	7	NON	EQL	11.6	11.6	11.6	11.6

Table 10 continued

SPECIES	CAGE WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
BOBWHITE	1:2 12	NC/LA	7	NON	IPC	11.6	11.6	11.6	11.6
		NC/LA	8	FTB	BIN	14.8	15.5	12.4	12.6
		NC/LA	8	FTB	EQL	14.7	15.2	12.2	12.6
		NC/LA	8	LGT	BIN	13.2	13.7	11.2	11.5
		NC/LA	8	LGT	EQL	13.1	13.5	11.0	11.2
		NC/LA	8	NON	BIN	16.6	17.4	13.7	14.1
		NC/LA	8	NON	EQL	16.5	17.2	13.7	14.0
		NC/LA	8	NON	IPC	16.3	17.0	13.6	13.9
		HA/SE	2	FTB	BIN	36.4	39.5	38.7	33.0
		HA/SE	2	FTB	EQL	34.8	37.8	37.2	32.4
		HA/SE	2	LGT	BIN	49.7	54.3	52.4	45.1
		HA/SE	2	LGT	EQL	46.3	50.3	49.0	43.3
		HA/SE	2	NON	BIN	32.3	35.1	34.5	29.5
		HA/SE	2	NON	EQL	31.2	34.0	33.4	29.1
		HA/SE	2	NON	IPC	31.0	33.8	33.3	29.0
		HA/SE	3	FTB	BIN	37.1	30.7	38.2	33.9
		HA/SE	3	FTB	EQL	35.6	29.9	36.9	33.8
		HA/SE	3	LGT	BIN	51.2	43.2	52.4	46.9
		HA/SE	3	LGT	EQL	47.2	39.9	48.9	45.6
		HA/SE	3	NON	BIN	33.0	27.4	34.0	30.4
		HA/SE	3	NON	EQL	32.1	26.8	33.4	30.5
		HA/SE	3	NON	IPC	32.0	26.6	33.3	30.4
		HA/SE	4	FTB	BIN	36.3	33.0	36.5	38.7
		HA/SE	4	FTB	EQL	35.0	31.6	35.3	37.9
		HA/SE	4	LGT	BIN	50.7	45.6	49.8	52.3
		HA/SE	4	LGT	EQL	46.3	42.0	46.4	50.1
		HA/SE	4	NON	BIN	32.9	29.7	32.7	35.0
		HA/SE	4	NON	EQL	31.7	28.5	31.8	34.5
		HA/SE	4	NON	IPC	31.6	28.4	31.7	34.4
		HA/SE	5	FTB	BIN	35.9	36.0	37.8	32.5
		HA/SE	5	FTB	EQL	34.7	34.7	36.7	32.0
		HA/SE	5	LGT	BIN	48.3	48.4	50.5	44.4
		HA/SE	5	LGT	EQL	45.7	46.1	47.9	42.4
		HA/SE	5	NON	BIN	32.5	32.5	34.4	29.5
		HA/SE	5	NON	EQL	31.4	31.3	33.1	29.0
		HA/SE	5	NON	IPC	31.2	31.2	33.1	28.9
		HA/SE	6	FTB	BIN	36.8	36.3	37.0	39.5
		HA/SE	6	FTB	EQL	35.6	35.2	36.2	39.1
		HA/SE	6	LGT	BIN	48.0	47.6	48.9	51.5
		HA/SE	6	LGT	EQL	45.2	44.7	46.0	49.2
		HA/SE	6	NON	BIN	33.8	33.4	34.0	36.4
		HA/SE	6	NON	EQL	32.8	32.4	33.3	36.2
		HA/SE	6	NON	IPC	32.7	32.3	33.2	36.1
		HA/SE	7	FTB	BIN	33.7	33.7	33.9	33.7
		HA/SE	7	FTB	EQL	32.1	32.1	32.3	32.1
		HA/SE	7	LGT	BIN	45.1	45.1	45.4	45.3
		HA/SE	7	LGT	EQL	41.9	41.9	42.2	42.0
		HA/SE	7	NON	BIN	30.6	30.6	30.7	30.6

Table 10 continued

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
BOBWHITE	1:2	12	HA/SE	7	NON	EQL	29.4	29.4	29.5	29.4
			HA/SE	7	NON	IPC	29.2	29.2	29.4	29.2
			HA/SE	8	FTB	BIN	48.7	50.1	41.8	42.6
			HA/SE	8	FTB	EQL	46.7	48.0	40.0	40.9
			HA/SE	8	LGT	BIN	61.2	62.8	54.6	55.0
			HA/SE	8	LGT	EQL	58.3	59.8	51.6	52.6
			HA/SE	8	NON	BIN	45.0	46.4	38.4	39.0
			HA/SE	8	NON	EQL	43.2	44.6	36.6	37.5
			HA/SE	8	NON	IPC	43.3	44.6	36.6	37.4
MALLARD	1:1	8	LAID	2	NON	EQL	24.9	27.4	26.8	23.2
			LAID	3	NON	EQL	24.1	19.8	25.4	22.7
			LAID	4	NON	EQL	24.0	21.9	24.5	26.7
			LAID	5	NON	EQL	23.3	23.3	24.7	21.1
			LAID	6	NON	EQL	24.0	23.7	24.7	26.9
			LAID	7	NON	EQL	21.9	21.9	22.0	21.9
			LAID	8	NON	EQL	32.9	34.3	27.5	28.2
			HA/SE	2	FTB	BIN	28.4	31.4	30.7	26.7
			HA/SE	2	FTB	EQL	28.3	31.3	30.5	26.7
			HA/SE	2	LGT	BIN	31.5	34.6	34.0	29.3
			HA/SE	2	LGT	EQL	31.1	34.4	33.5	29.3
			HA/SE	2	NON	BIN	27.6	30.4	29.7	26.0
			HA/SE	2	NON	EQL	27.5	30.2	29.6	26.0
			HA/SE	2	NON	IPC	27.4	30.2	29.5	25.9
			HA/SE	3	FTB	BIN	28.4	23.6	29.7	27.0
			HA/SE	3	FTB	EQL	28.3	23.2	29.6	27.0
			HA/SE	3	LGT	BIN	31.1	25.6	32.4	29.2
			HA/SE	3	LGT	EQL	30.7	25.2	32.2	29.2
			HA/SE	3	NON	BIN	27.8	23.2	28.9	26.5
			HA/SE	3	NON	EQL	27.5	22.7	28.8	26.4
			HA/SE	3	NON	IPC	27.5	22.7	28.8	26.4
			HA/SE	4	FTB	BIN	29.7	26.5	29.4	32.1
			HA/SE	4	FTB	EQL	29.2	26.1	29.2	31.9
			HA/SE	4	LGT	BIN	31.9	28.5	31.7	34.3
			HA/SE	4	LGT	EQL	31.3	28.1	31.4	34.2
			HA/SE	4	NON	BIN	29.0	26.1	29.1	31.6
			HA/SE	4	NON	EQL	28.8	25.8	28.7	31.4
			HA/SE	4	NON	IPC	28.8	25.7	28.7	31.4
			HA/SE	5	FTB	BIN	28.2	28.0	29.9	26.0
			HA/SE	5	FTB	EQL	27.6	27.6	29.4	25.7
			HA/SE	5	LGT	BIN	30.3	30.3	32.3	27.7
			HA/SE	5	LGT	EQL	29.8	29.8	31.8	27.5
			HA/SE	5	NON	BIN	27.6	27.5	29.4	25.9
			HA/SE	5	NON	EQL	27.3	27.2	28.9	25.5
			HA/SE	5	NON	IPC	27.2	27.2	28.9	25.5
			HA/SE	6	FTB	BIN	29.5	29.0	30.0	32.7
			HA/SE	6	FTB	EQL	29.0	28.6	29.6	32.4
			HA/SE	6	LGT	BIN	31.4	30.9	31.9	34.7
			HA/SE	6	LGT	EQL	30.9	30.4	31.5	34.3

Table 10 continued

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
MALLARD	1:1	8	HA/SE	6	NON	BIN	29.2	28.8	29.7	32.5
			HA/SE	6	NON	EQL	28.7	28.3	29.4	32.3
			HA/SE	6	NON	IPC	28.7	28.3	29.3	32.2
			HA/SE	7	FTB	BIN	27.8	27.8	27.9	27.8
			HA/SE	7	FTB	EQL	27.3	27.3	27.4	27.3
			HA/SE	7	LGT	BIN	29.8	29.8	29.9	29.8
			HA/SE	7	LGT	EQL	29.3	29.3	29.4	29.3
			HA/SE	7	NON	BIN	27.5	27.5	27.6	27.5
			HA/SE	7	NON	EQL	27.0	27.0	27.1	27.0
			HA/SE	7	NON	IPC	27.0	27.0	27.1	27.0
			HA/SE	8	FTB	BIN	40.5	42.1	33.7	34.5
			HA/SE	8	FTB	EQL	39.6	41.1	33.0	33.8
			HA/SE	8	LGT	BIN	41.9	43.6	35.2	36.1
			HA/SE	8	LGT	EQL	40.9	42.5	34.6	35.4
			HA/SE	8	NON	BIN	40.4	42.1	33.7	34.5
			HA/SE	8	NON	EQL	39.5	41.0	33.0	33.8
			HA/SE	8	NON	IPC	39.6	41.1	33.0	33.8
MALLARD	2:5	8	LAID	2	NON	EQL	17.8	19.4	19.0	16.9
			LAID	3	NON	EQL	17.9	15.1	18.6	17.1
			LAID	4	NON	EQL	18.1	16.5	18.4	19.8
			LAID	5	NON	EQL	17.8	17.9	18.8	16.9
			LAID	6	NON	EQL	17.7	17.5	18.0	19.3
			LAID	7	NON	EQL	17.5	17.5	17.5	17.5
			LAID	8	NON	EQL	23.3	24.0	20.0	20.4
			NC/LA	2	FTB	BIN	3.6	3.8	3.7	4.0
			NC/LA	2	FTB	EQL	3.9	3.9	3.8	3.8
			NC/LA	2	LGT	BIN	4.0	4.3	4.2	4.0
			NC/LA	2	LGT	EQL	4.0	4.3	4.2	3.9
			NC/LA	2	NON	BIN	3.5	3.4	3.6	3.9
			NC/LA	2	NON	EQL	3.5	3.7	3.8	4.0
			NC/LA	2	NON	IPC	3.4	3.7	3.8	4.0
			NC/LA	3	FTB	BIN	3.6	3.7	3.6	3.4
			NC/LA	3	FTB	EQL	3.8	3.2	4.0	3.7
			NC/LA	3	LGT	BIN	3.7	3.4	3.9	3.7
			NC/LA	3	LGT	EQL	3.9	3.2	4.0	3.7
			NC/LA	3	NON	BIN	3.8	3.3	3.6	3.7
			NC/LA	3	NON	EQL	4.1	3.5	4.0	4.0
			NC/LA	3	NON	IPC	4.0	3.5	4.0	3.9
			NC/LA	4	FTB	BIN	4.1	3.9	4.1	4.5
			NC/LA	4	FTB	EQL	4.0	3.8	3.9	4.6
			NC/LA	4	LGT	BIN	3.9	3.9	3.8	4.3
			NC/LA	4	LGT	EQL	3.7	3.6	3.8	4.4
			NC/LA	4	NON	BIN	4.5	4.2	4.3	5.0
			NC/LA	4	NON	EQL	4.5	4.2	4.3	5.1
			NC/LA	4	NON	IPC	4.5	4.1	4.3	5.1
			NC/LA	5	FTB	BIN	4.3	4.3	4.5	4.4
			NC/LA	5	FTB	EQL	4.4	4.3	4.6	4.3
			NC/LA	5	LGT	BIN	3.6	3.6	3.8	4.0

Table 10 continued

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
MALLARD	2:5	8	NC/LA	5	LGT	EQL	3.9	3.9	4.0	4.2
			NC/LA	5	NON	BIN	5.9	5.9	6.3	6.1
			NC/LA	5	NON	EQL	6.0	6.0	6.4	6.2
			NC/LA	5	NON	IPC	6.0	5.9	6.3	6.2
			NC/LA	6	FTB	BIN	4.7	4.6	4.7	5.2
			NC/LA	6	FTB	EQL	4.8	4.7	4.8	5.4
			NC/LA	6	LGT	BIN	3.7	3.7	3.8	4.3
			NC/LA	6	LGT	EQL	4.1	4.0	4.1	4.4
			NC/LA	6	NON	BIN	6.0	5.9	6.0	7.0
			NC/LA	6	NON	EQL	6.1	6.0	6.2	7.2
			NC/LA	6	NON	IPC	6.0	6.0	6.2	7.2
			NC/LA	7	FTB	BIN	5.4	5.4	5.3	5.4
			NC/LA	7	FTB	EQL	5.6	5.6	5.5	5.6
			NC/LA	7	LGT	BIN	3.8	3.8	3.7	3.7
			NC/LA	7	LGT	EQL	4.0	4.0	4.0	4.0
			NC/LA	7	NON	BIN	8.4	8.4	8.4	8.4
			NC/LA	7	NON	EQL	8.7	8.7	8.7	8.7
			NC/LA	7	NON	IPC	8.6	8.6	8.6	8.6
			NC/LA	8	FTB	BIN	6.4	6.6	5.2	5.4
			NC/LA	8	FTB	EQL	6.4	6.6	5.2	5.5
			NC/LA	8	LGT	BIN	5.2	5.3	4.3	4.5
			NC/LA	8	LGT	EQL	5.3	5.4	4.3	4.5
			NC/LA	8	NON	BIN	8.1	8.6	6.5	6.8
			NC/LA	8	NON	EQL	8.2	8.7	6.6	6.9
			NC/LA	8	NON	IPC	8.2	8.6	6.6	6.9
			HA/SE	2	FTB	BIN	11.5	12.6	12.4	10.9
			HA/SE	2	FTB	EQL	11.5	12.4	12.4	10.9
			HA/SE	2	LGT	BIN	11.6	12.7	12.6	11.0
			HA/SE	2	LGT	EQL	11.6	12.6	12.6	11.0
			HA/SE	2	NON	BIN	11.4	12.5	12.3	10.8
			HA/SE	2	NON	EQL	11.4	12.3	12.3	10.9
			HA/SE	2	NON	IPC	11.4	12.3	12.2	10.8
			HA/SE	3	FTB	BIN	11.3	9.5	11.9	10.8
			HA/SE	3	FTB	EQL	11.3	9.5	12.0	11.0
			HA/SE	3	LGT	BIN	11.4	9.5	12.0	10.8
			HA/SE	3	LGT	EQL	11.4	9.5	12.0	11.0
			HA/SE	3	NON	BIN	11.3	9.5	11.9	10.8
			HA/SE	3	NON	EQL	11.3	9.4	11.9	11.0
			HA/SE	3	NON	IPC	11.3	9.4	11.9	10.9
			HA/SE	4	FTB	BIN	11.3	10.3	11.4	12.5
			HA/SE	4	FTB	EQL	11.4	10.4	11.5	12.6
			HA/SE	4	LGT	BIN	11.3	10.3	11.4	12.5
			HA/SE	4	LGT	EQL	11.3	10.4	11.5	12.6
			HA/SE	4	NON	BIN	11.3	10.4	11.4	12.5
			HA/SE	4	NON	EQL	11.4	10.4	11.5	12.6
			HA/SE	4	NON	IPC	11.3	10.4	11.5	12.6
			HA/SE	5	FTB	BIN	11.2	11.2	11.9	10.5
			HA/SE	5	FTB	EQL	11.1	11.1	11.8	10.4

Table 10 continued

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
MALLARD	2:5	8	HA/SE	5	LGT	BIN	11.4	11.3	12.1	10.6
			HA/SE	5	LGT	EQL	11.3	11.3	12.0	10.6
			HA/SE	5	NON	BIN	11.1	11.0	11.7	10.4
			HA/SE	5	NON	EQL	11.0	11.0	11.7	10.3
			HA/SE	5	NON	IPC	11.0	11.0	11.6	10.3
			HA/SE	6	FTB	BIN	11.9	11.8	12.2	13.3
			HA/SE	6	FTB	EQL	11.9	11.8	12.2	13.4
			HA/SE	6	LGT	BIN	12.0	11.8	12.2	13.4
			HA/SE	6	LGT	EQL	11.9	11.8	12.2	13.4
			HA/SE	6	NON	BIN	11.9	11.8	12.2	13.3
			HA/SE	6	NON	EQL	11.9	11.7	12.2	13.4
			HA/SE	6	NON	IPC	11.8	11.7	12.1	13.3
			HA/SE	7	FTB	BIN	11.1	11.1	11.1	11.1
			HA/SE	7	FTB	EQL	11.1	11.1	11.1	11.1
			HA/SE	7	LGT	BIN	11.6	11.6	11.6	11.6
			HA/SE	7	LGT	EQL	11.7	11.7	11.7	11.7
			HA/SE	7	NON	BIN	10.7	10.7	10.7	10.7
			HA/SE	7	NON	EQL	10.7	10.7	10.7	10.7
			HA/SE	7	NON	IPC	10.6	10.6	10.6	10.6
			HA/SE	8	FTB	BIN	16.0	16.6	13.6	14.0
			HA/SE	8	FTB	EQL	16.0	16.5	13.5	13.8
			HA/SE	8	LGT	BIN	15.9	16.5	13.5	13.9
			HA/SE	8	LGT	EQL	15.9	16.4	13.4	13.8
			HA/SE	8	NON	BIN	16.0	16.6	13.6	14.0
			HA/SE	8	NON	EQL	16.0	16.6	13.5	13.9
			HA/SE	8	NON	IPC	16.0	16.5	13.5	13.8
MALLARD	2:5	12	LAID	2	NON	EQL	18.7	20.2	20.0	17.9
			LAID	3	NON	EQL	19.3	16.4	20.2	18.4
			LAID	4	NON	EQL	19.4	17.5	19.5	20.7
			LAID	5	NON	EQL	19.4	19.6	20.5	18.3
			LAID	6	NON	EQL	19.0	18.9	19.6	20.9
			LAID	7	NON	EQL	18.8	18.8	18.9	18.8
			LAID	8	NON	EQL	24.9	25.7	22.0	22.2
			NC/LA	2	LGT	BIN	.	4.0	.	.
			NC/LA	2	LGT	EQL	.	.	5.0	.
			NC/LA	3	FTB	EQL	.	.	4.9	4.9
			NC/LA	3	LGT	BIN	.	.	4.9	.
			NC/LA	3	LGT	EQL	5.0	.	5.0	.
			NC/LA	3	NON	EQL	.	.	5.0	.
			NC/LA	4	FTB	BIN	4.4	.	.	4.5
			NC/LA	4	FTB	EQL	4.3	.	.	4.3
			NC/LA	4	LGT	BIN	.	.	.	5.0
			NC/LA	4	LGT	EQL	4.1	.	.	5.2
			NC/LA	4	NON	BIN	4.6	4.4	5.0	4.9
			NC/LA	4	NON	EQL	4.5	4.1	5.1	4.7
			NC/LA	4	NON	IPC	4.5	.	5.1	4.5
			NC/LA	5	FTB	BIN	4.6	4.7	4.8	4.2
			NC/LA	5	FTB	EQL	4.7	4.7	4.8	.

Table 10 continued

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
MALLARD	2:5	12	NC/LA	5	LGT	EQL	4.7	4.7	4.8	.
			NC/LA	5	NON	BIN	4.2	4.2	4.3	4.2
			NC/LA	5	NON	EQL	4.0	4.0	4.2	4.1
			NC/LA	5	NON	IPC	4.1	4.1	4.2	4.2
			NC/LA	6	FTB	BIN	4.4	4.2	3.6	3.5
			NC/LA	6	FTB	EQL	4.5	4.5	4.5	3.5
			NC/LA	6	LGT	BIN	.	.	3.6	3.4
			NC/LA	6	LGT	EQL	4.9	4.9	4.1	3.1
			NC/LA	6	NON	BIN	4.4	4.4	4.3	4.6
			NC/LA	6	NON	EQL	4.1	4.1	4.2	4.6
			NC/LA	6	NON	IPC	4.2	4.4	4.1	4.5
			NC/LA	7	FTB	BIN	4.1	4.1	4.1	4.1
			NC/LA	7	FTB	EQL	4.2	4.2	4.2	4.2
			NC/LA	7	NON	BIN	5.1	5.1	5.1	5.1
			NC/LA	7	NON	EQL	5.2	5.2	5.2	5.2
			NC/LA	7	NON	IPC	5.2	5.2	5.2	5.2
			NC/LA	8	FTB	BIN	5.3	4.4	4.7	4.9
			NC/LA	8	FTB	EQL	4.9	4.4	4.6	4.6
			NC/LA	8	LGT	BIN	5.2	4.7	4.9	4.9
			NC/LA	8	LGT	EQL	5.1	5.3	4.8	4.8
			NC/LA	8	NON	BIN	5.0	5.0	4.3	4.4
			NC/LA	8	NON	EQL	5.0	5.0	4.3	4.5
			NC/LA	8	NON	IPC	4.9	5.0	4.3	4.4
			HA/SE	2	FTB	BIN	15.3	16.9	16.4	14.6
			HA/SE	2	FTB	EQL	15.2	16.7	16.3	14.5
			HA/SE	2	LGT	BIN	15.3	16.8	16.3	14.5
			HA/SE	2	LGT	EQL	15.2	16.6	16.3	14.5
			HA/SE	2	NON	BIN	15.3	17.0	16.4	14.6
			HA/SE	2	NON	EQL	15.3	16.8	16.4	14.6
			HA/SE	2	NON	IPC	15.2	16.7	16.3	14.6
			HA/SE	3	FTB	BIN	15.2	12.7	16.0	14.5
			HA/SE	3	FTB	EQL	15.2	12.6	16.0	14.5
			HA/SE	3	LGT	BIN	15.2	12.7	15.9	14.5
			HA/SE	3	LGT	EQL	15.1	12.6	15.9	14.4
			HA/SE	3	NON	BIN	15.3	12.7	16.0	14.5
			HA/SE	3	NON	EQL	15.2	12.6	16.0	14.5
			HA/SE	3	NON	IPC	15.2	12.6	15.9	14.5
			HA/SE	4	FTB	BIN	15.5	14.1	15.7	16.8
			HA/SE	4	FTB	EQL	15.4	14.0	15.7	16.9
			HA/SE	4	LGT	BIN	15.5	14.2	15.7	16.8
			HA/SE	4	LGT	EQL	15.4	14.0	15.7	16.9
			HA/SE	4	NON	BIN	15.5	14.2	15.7	16.9
			HA/SE	4	NON	EQL	15.4	14.0	15.7	17.0
			HA/SE	4	NON	IPC	15.4	14.0	15.8	16.9
			HA/SE	5	FTB	BIN	15.0	15.0	15.8	14.0
			HA/SE	5	FTB	EQL	14.9	14.9	15.7	14.0
			HA/SE	5	LGT	BIN	15.3	15.3	16.1	14.4
			HA/SE	5	LGT	EQL	15.2	15.2	15.9	14.3

Table 10 continued

SPECIES	CAGE	WEEKS	VAR	PTRN	TRAN	WT.	SEQT	SREG	WILL	EBAR
MALLARD	2:5	12	HA/SE	5	NON	BIN	14.8	14.8	15.6	13.8
			HA/SE	5	NON	EQL	14.7	14.8	15.5	13.7
			HA/SE	5	NON	IPC	14.7	14.7	15.4	13.7
			HA/SE	6	FTB	BIN	15.3	15.1	15.6	16.9
			HA/SE	6	FTB	EQL	15.2	15.1	15.6	16.9
			HA/SE	6	LGT	BIN	15.4	15.3	15.8	17.1
			HA/SE	6	LGT	EQL	15.4	15.2	15.8	17.1
			HA/SE	6	NON	BIN	15.2	15.1	15.5	16.7
			HA/SE	6	NON	EQL	15.2	15.0	15.5	16.7
			HA/SE	6	NON	IPC	15.1	15.0	15.5	16.7
			HA/SE	7	FTB	BIN	14.0	14.0	14.0	14.0
			HA/SE	7	FTB	EQL	14.0	14.0	14.0	14.0
			HA/SE	7	LGT	BIN	15.0	15.0	15.1	15.0
			HA/SE	7	LGT	EQL	15.1	15.1	15.1	15.1
			HA/SE	7	NON	BIN	13.3	13.3	13.3	13.3
			HA/SE	7	NON	EQL	13.3	13.3	13.3	13.3
			HA/SE	7	NON	IPC	13.3	13.3	13.3	13.3
			HA/SE	8	FTB	BIN	20.3	20.9	17.4	17.7
			HA/SE	8	FTB	EQL	20.1	20.8	17.3	17.7
			HA/SE	8	LGT	BIN	20.4	21.0	17.5	17.8
			HA/SE	8	LGT	EQL	20.3	21.0	17.4	17.8
			HA/SE	8	NON	BIN	20.2	20.9	17.3	17.6
			HA/SE	8	NON	EQL	20.0	20.7	17.2	17.6
			HA/SE	8	NON	IPC	20.0	20.7	17.2	17.6

- table entries show the estimated sample size required to provide 80% power of detecting the lowest dose which causes a 20% decline in the variable being analyzed. Calculations were based on fitting a logistic curve to each of 5 independent simulations and averaging the results. If all 5 simulations could not be used to estimate the sample size the table entry was left blank.

Table 11: Required number of pens at each treatment level giving 80% power of detecting the smallest dose causing a 20 % decline in the affected variable over all 7 active treatment patterns (i.e. patterns 2-8)

BOBWHITE: 1:1 CAGING: 8 WEEK TEST

VAR	TRANS	WT.	SEQT	SREG	WILL	EBAR
LAID	NON	EQL	84	86	74	76
NC/LA	FTB	BIN		12		
NC/LA	FTB	EQL	13	12	14(6)	13(6)
NC/LA	LGT	BIN	12(6)	a	a	12(6)
NC/LA	LGT	EQL	12(6)	12(6)	12(6)	12(6)
NC/LA	NON	BIN	13	11	15(6)	14(6)
NC/LA	NON	EQL	12(6)	12(7)	12(6)	12(4)
NC/LA	NON	IPC	14	14(7)	14(7)	14(7)
HA/SE	FTB	BIN	a	a	a	a
HA/SE	FTB	EQL	34	35	28	29
HA/SE	LGT	BIN	a	a	a	a
HA/SE	LGT	EQL	33	34	27	28
HA/SE	NON	BIN	a	a	a	30
HA/SE	NON	EQL	36	37	29	30
HA/SE	NON	IPC	35	36	29	29

BOBWHITE: 1:1 CAGING: 12 WEEK TEST

VAR	TRANS	WT.	SEQT	SREG	WILL	EBAR
LAID	NON	EQL	74	75	66	67
NC/LA	FTB	BIN	14	15	13	13
NC/LA	FTB	EQL	15	15	13	13
NC/LA	LGT	BIN	b	b	b	12
NC/LA	LGT	EQL	14	14	12	12
NC/LA	NON	BIN	16	16	13	13
NC/LA	NON	EQL	17	17	14	14
NC/LA	NON	IPC	16	17	14	14
HA/SE	FTB	BIN	a	a	a	a
HA/SE	FTB	EQL	37(4)	39(2)	38(5)	40(4)
HA/SE	LGT	BIN	a	a	a	a
HA/SE	LGT	EQL	37(2)	40(2)	39(2)	40(4)
HA/SE	NON	BIN	a	a	a	42(6)
HA/SE	NON	EQL	37(4)	40	39(5)	41(6)
HA/SE	NON	IPC	37(4)	40	38(5)	40(6)

Table 11: continued

BOBWHITE: 1:2 CAGING: 8 WEEK TEST

VAR	TRANS	WT.	SEQT	SREG	WILL	EBAR
LAID	NON	EQL	66	67	57	58
NC/LA	FTB	BIN	16	17	13	14
NC/LA	FTB	EQL	17	17	14	14
NC/LA	LGT	BIN	a	a	a	b
NC/LA	LGT	EQL	15	15	13	13
NC/LA	NON	BIN	18	19	15	15
NC/LA	NON	EQL	19	20	15	16
NC/LA	NON	IPC	18	19	15	15
HA/SE	FTB	BIN	a	a	a	43
HA/SE	FTB	EQL	47	48	40	41
HA/SE	LGT	BIN	a	a	a	52
HA/SE	LGT	EQL	55	56	48	49
HA/SE	NON	BIN	a	a	a	49
HA/SE	NON	EQL	44	45	37	38
HA/SE	NON	IPC	43	44	37	38

BOBWHITE: 1:2 CAGING: 12 WEEK TEST

VAR	TRANS	WT.	SEQT	SREG	WILL	EBAR
LAID	NON	EQL	55	56	47	48
NC/LA	FTB	BIN	15	16	13	13
NC/LA	FTB	EQL	15	16	13	13
NC/LA	LGT	BIN	14	14	12	12
NC/LA	LGT	EQL	14	14	11	12
NC/LA	NON	BIN	17	18	14	15
NC/LA	NON	EQL	17	18	14	15
NC/LA	NON	IPC	17	17	14	14
HA/SE	FTB	BIN	49	51	42	43
HA/SE	FTB	EQL	47	49	41	41
HA/SE	LGT	BIN	b	b	b	b
HA/SE	LGT	EQL	59	60	52	53
HA/SE	NON	BIN	46	47	39	40
HA/SE	NON	EQL	44	47	37	38
HA/SE	NON	IPC	44	45	37	38

Table 11: continued

MALLARD: 1:1 CAGING: 8 WEEK TEST

VAR	TRANS	WT.	SEQT	SREG	WILL	EBAR
LAI	NON	EQL	33	35	28	29
NC/LA	FTB	BIN	<16	<16	<16	<16
NC/LA	FTB	EQL	<16	<16	<16	<16
NC/LA	LGT	BIN	b	b	b	b
NC/LA	LGT	EQL	<16	<16	<16	<16
NC/LA	NON	BIN	<16	<16	<16	<16
NC/LA	NON	EQL	<16	<16	<16	<16
NC/LA	NON	IPC	<16	<16	<16	<16
HA/SE	FTB	BIN	41	43	34	35
HA/SE	FTB	EQL	40	41	34	34
HA/SE	LGT	BIN	42	44	36	37
HA/SE	LGT	EQL	41	43	35	36
HA/SE	NON	BIN	41	43	34	35
HA/SE	NON	EQL	40	41	34	34
HA/SE	NON	IPC	40	42	34	34

MALLARD: 2:5 CAGING: 8 WEEK TEST

VAR	TRANS	WT.	SEQT	SREG	WILL	EBAR
LAI	NON	EQL	24	24	20	21
NC/LA	FTB	BIN	7	7	6	6
NC/LA	FTB	EQL	7	7	6	6
NC/LA	LGT	BIN	6	6	5	5
NC/LA	LGT	EQL	6	6	5	5
NC/LA	NON	BIN	9(7)	9	9(7)	9(7)
NC/LA	NON	EQL	9	9(7)	9(7)	9(7)
NC/LA	NON	IPC	9(7)	9(7)	9(7)	9(7)
HA/SE	FTB	BIN	16	17	14	14
HA/SE	FTB	EQL	16	17	14	14
HA/SE	LGT	BIN	16	17	14	14
HA/SE	LGT	EQL	16	17	14	14
HA/SE	NON	BIN	17	17	14	15
HA/SE	NON	EQL	17	17	14	14
HA/SE	NON	IPC	16	17	14	14

Table 11: continued

MALLARD: 2:5 CAGING: 12 WEEK TEST

VAR	TRANS	WT.	SEQT	SREG	WILL	EBAR
LAID	NON	EQL	25	26	22	23
NC/LA	FTB	BIN	6	5	5(4)	5
NC/LA	FTB	EQL	5	5(5)	5(2)	5(2)
NC/LA	LGT	BIN	6	5	5(3)	5(4)
NC/LA	LGT	EQL	6	6	5(3)	6(4)
NC/LA	NON	BIN	6(7)	6(7)	6(7)	6(7)
NC/LA	NON	EQL	6(7)	6(7)	6(7)	6(7)
NC/LA	NON	IPC	6(7)	6(7)	6(7)	6(7)
HA/SE	FTB	BIN	21	21	18	18
HA/SE	FTB	EQL	21	21	18	18
HA/SE	LGT	BIN	21	22	18	18
HA/SE	LGT	EQL	21	22	18	18
HA/SE	NON	BIN	21	21	18	18
HA/SE	NON	EQL	21	21	18	18
HA/SE	NON	IPC	21	21	18	18

- table entries show minimum required sample size over all 7 active treatment patterns generally this is required for pattern 8 except where indicated in brackets. If sample size was not estimable for any pattern (Table 10) then the entry was left blank.

a - failed nominal significance level

b - failed partial significance level for at least one pattern

Table 12: Summary of required number of pens to provide 80% power to detect NOEL over 7 active treatment patterns (patterns 2-8).

SPECIES	CAGING	WEEKS	LAI D	PROPORTION NON-CRACKED	PROPORTION HATCHED
BOBWHITE	1:1	8	74	12	27
		12	66	12	39
	1:2	8	57	13	27
		12	47	11	37
MALLARD	1:1	8	28	<16	34
	2:5	8	20	5	14
		12	22	5	18

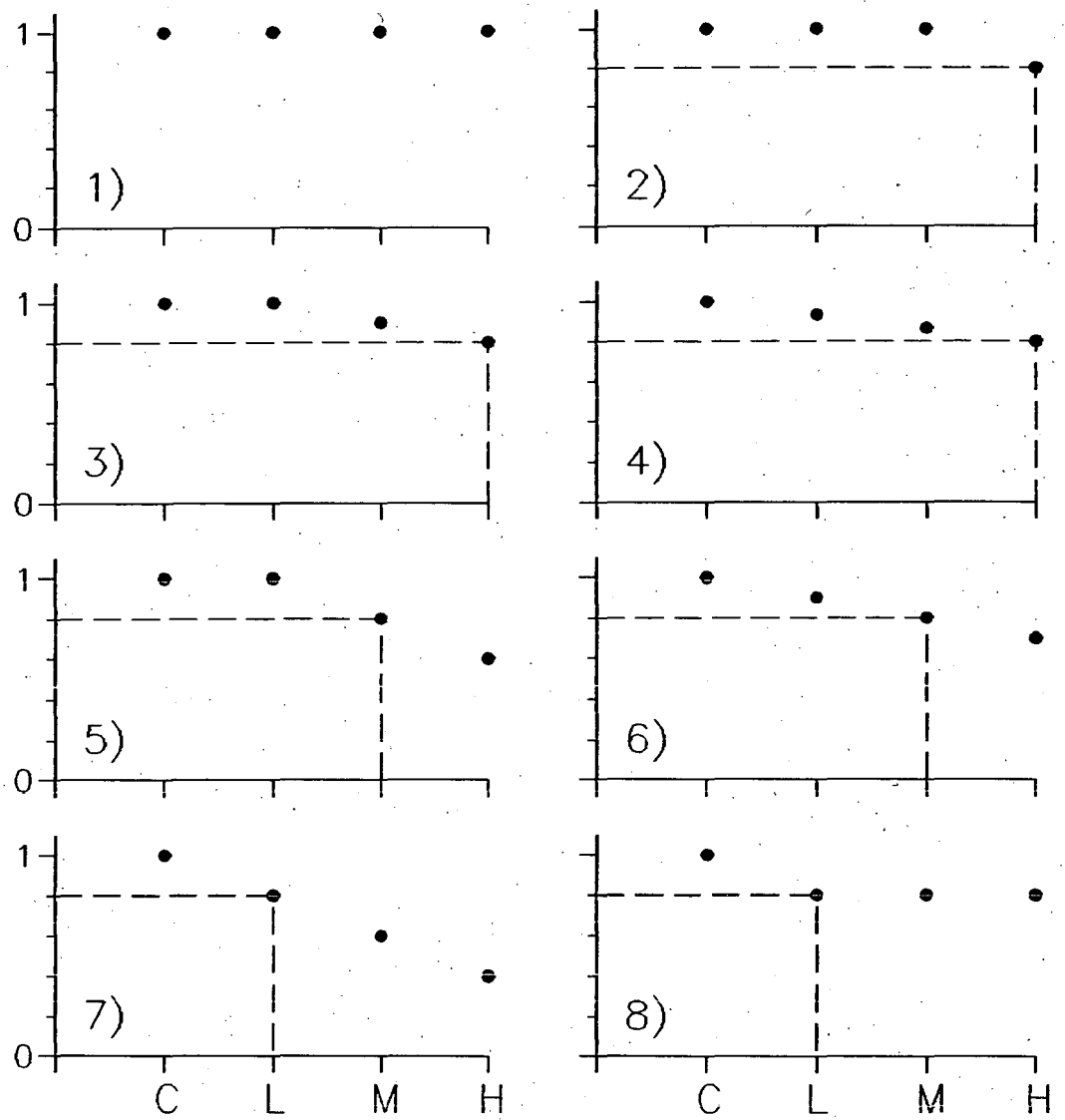


Figure 1: Patterns of treatment effect

Figure 2: Power of detecting  
a decline to 80% of control  
Bobwhite: 1:1 caging: 8 week test  
LAID: Pattern 2: William's Test

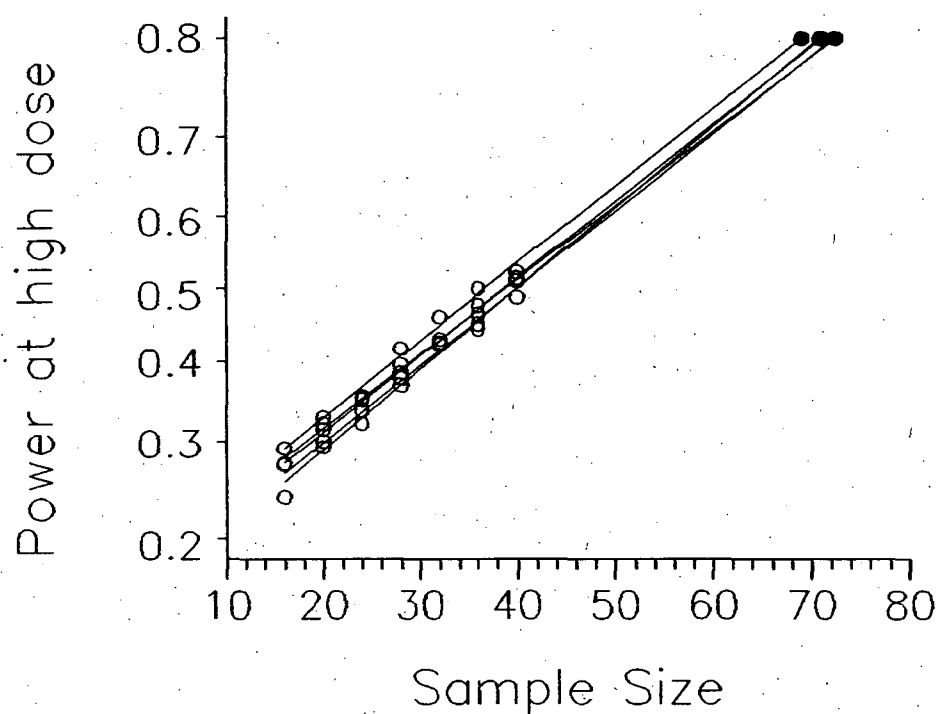


Figure 3: Power of detecting  
a decline to 80% of control  
Bobwhite: 1:1 caging: 8 week test  
HA/SE: Pattern 2: William's Test  
Logit transformed: Equal Weighting

