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Adjusting for Nonresponse in the December Enumerative Survey

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ADJUSTING FOR NONRESPONSE IN THE DECEMBER ENUMERATIVE SURVEY

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ABSTRACT

This study evaluated two automated procedures which adjust for entire farm non-response in the December Enumerative Survey area frame. Farm and weighted estimates for four hog and four cattle variables were compared to the operational procedure of subjectively imputing data for all nonrespondents. The study, conducted in six states, was a follow-up to a similiar study done for the 1983 June Enumerative Survey (JES). Both DES procedures appeared to be reasonable alternatives to the operational. Differences in estimates were generally insignificant and both procedures eliminated the variability by state found to exist under current imputation procedures. However, Procedure 2 which makes use of information on livestock presence was recommended. Procedure 2 was based on more reasonable assumptions and is analagous to the procedure tentatively recommended in the JES study.

ACKNOWLEDGE-MENTS

The author thanks the Georgia, Illinois, Iowa, Kansas, Ohio, and Wyoming SSO's for the additional data collection efforts required for this study. The previous work of Dave Dillard and Barry Ford (3) provided the pattern for this analysis and report. Finally, thanks go to Eldon Thiessen for his thorough final review and subsequent suggestions.

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SUMMARY

The goal of this study was to find a consistent, objective procedure for dealing with area frame non-response to cattle or hog items at the entire farm level which could replace the present manual imputation without adversely affecting the estimates. Currently, imputation is highly subjective, time consuming, and varies in its application from state to state.

Two procedures which adjust hog and cattle estimates without using data manually imputed in the field were evaluated for four hog and four cattle variables. Data in six states from the 1983 DES were included - Georgia, Illinois, Iowa, Kansas, Ohio, and Wyoming. The area frame contributions to the farm, the weighted, and the nonoverlap estimates were considered.

Procedure 1 assumed that within each DES summary stratum the nonrespondents were like respondents. Procedure 2 assumed that within each summary stratum the nonrespondents who had hogs/cattle were like the respondents who had hogs/cattle. When it was unknown if a nonrespondent had hogs/cattle, then it was assumed that the nonrespondent was like respondents and known nonrespondents combined.

Procedure 2 was recommended to replace the operational. For most variables, both test procedures gave estimates which were not significantly different from the operational. However, estimates from both tended to be higher. This was particularly true for Procedure 2. The assumptions under Procedure 1 seemed intuitively suspect and, in fact, in the DES a larger proportion of known nonrespondents had livestock than did respondents. Thus, Procedure 2 was based on more realistic assumptions. Those estimates that were significantly different under Procedure 2 were primarily for variables that were difficult for field staff to impute such as "hogs purchased". The same was also found true in the JES study (3). The potential downward bias in farm estimates of milk cows which surfaced in the JES study did not appear in the DES study.

PROCEDURES TO ADJUST FOR NONRESPONSE IN THE DECEMBER ENUMERATIVE SURVEY

INTRODUCTION

The December Enumerative Survey (DES) is based primarily on a nationwide area frame sample and is used in estimating year-end livestock inventories, fall planted crop acreages, and grain stocks. The sample is a subsample of area tracts previously enumerated in the June Enumerative Survey (JES). The JES is a major national mid-year survey consisting of area segments which are completely enumerated for livestock items and crop acreages. Currently field staff must impute all data for area frame nonrespondents in both the JES and DES.

Dillard and Ford (3) discussed the difficulties associated with this imputation, particularly for entire farm, non-inventory livestock items such as purchases or births. Data for crops are currently collected only for the tract (land within the area sample unit) and are more easily observed for nonrespondents. The same is true to a somewhat lesser extent for tract livestock data. Thus, both studies concentrated on alternative nonresponse adjustments for livestock estimates involving entire farm data.

BACKGROUND

Past research done by SRS concurs that nonrespondents tend to have livestock more often than do respondents. Crank (2) found this to be true for list frame surveys as did Dillard and Ford for the JES. With this in mind, Crank examined procedures which made use of additional information on livestock presence for nonrespondents. These procedures resulted in estimates that were 2 to 6 percent higher than the operational list estimates which assumed that nonrespondents were like respondents.

DESIGN OF THE STUDY

The design of this study was patterned after the similar study conducted for the JES (3). Two automated procedures were compared to the operational procedure of subjective imputation. The operational procedure was not considered as "truth" in any sense but was used only to measure the effects of the alternatives. Formulas for the procedures are described in Appendix A.

Both procedures made adjustments within summary strata. DES summary strata are described as follows. Each JES tract is post-stratified into a "summary stratum" based on its crops and livestock at the time of the JES interview. Tracts are also designated to a "select stratum" which may be different from the summary stratum due to some special characteristic, e.g. very large or nonoverlap. Select strata are used only to vary the sampling rate for unusual tracts. DES data are summarized by summary stratum. There were eight summary strata in the 1983 DES. An additional ten select strata were created for sampling purposes giving a total of 18 select strata. A brief description of the eight summary strata is given below using JES characteristics. Classification is on a priority basis beginning with Stratum 1.

DES SUMMARY STRATA

Stratum 1: Winter Wheat or Rye or Summerfallow, and Chickens
Stratum 2: Winter Wheat or Rye or Summerfallow
Stratum 3: Hogs and Chickens
Stratum 4: Chickens
Stratum 5: Hogs
Stratum 6: Cattle
Stratum 7: Other Ag tracts
Stratum 8: Non-Ag

Procedure 1 assumed that, within a summary stratum, livestock data for nonrespondents were distributed the same as for respondents. Data for nonrespondents were ignored and expansion factors for respondents multiplied by the ratio of the number of all farm operators in the stratum to the number of respondent farm operators. If a summary stratum was composed entirely of nonrespondents, a similar adjustment was made at the State level. This was rarely necessary involving only two tracts when restricted to nonoverlap farm estimates. This procedure was similiar to Ford's 1978 study (4).

Procedure 2 assumed that, within a summary stratum, data for nonrespondents with hogs/cattle were distributed the same as data for respondents with hogs/cattle. It further assumed that the proportion of unknown nonrespondents, i.e. hog/cattle presence was unknown, that actually had hogs/cattle was the same as that for respondents and known nonresondents combined. Procedure 2 required a classification of nonrespondents during data collection into one of three categories: 1) hogs/cattle present 2) no hogs/cattle 3) unknown if hogs/cattle present. Procedure 2 corresponded to those suggested by Crank (2) for list frame estimates.

Under both procedures there was a category for "nonrespondent with reliable information." Survey instructions defined this category to be "when the enumerator was able to observe reliable inventory data or obtain this data from other sources generally used." Further instructions stated that "the enumerator should have obtained reliable data for each inventory item." The test procedures considered manually imputed values in these cases as though they were reported data, i.e. the test procedures were applied only to nonrespondents without reliable data. This "reliable information" category represented only about 2 percent of the operations for both hogs and cattle.

The JES Study (3) considered similiar adjustments except that instead of summary strata, segments and paper strata were considered as "imputation domains" for Procedure 1 and paper strata for Procedure 2. The paucity of tracts within segment and paper stratum in the DES sample made these procedures unsuitable for the DES. For example considering farm estimates of cattle under Procedure 1, about 50% of the non-respondent tracts in the DES were in segments with no respondents and about 5% were in such paper strata. Of course many of the remaining segments and paper strata would have few respondent tracts on which to base adjustments. In these cases imputation could be done at broader level, e.g. land use strata or state, however summary strata, which are defined based on characteristics related to the variables of interest, served as more natural imputation regions.

Data were analyzed from the 1983 DES in six states: Georgia, Illinois, Iowa, Kansas, Ohio, and Wyoming. The states were selected because of their geographic diversity, varying nonresponse rates, and size of livestock inventories. Hog estimates were not analyzed in Wyoming because of the small number of hog operations.

Farm estimators were analyzed in all states and weighted estimators in all except Wyoming which did not collect data for weighted estimates. Farm and weighted estimators are described in Appendix A. Analysis was done both for the entire area frame excluding extreme operators and for the nonoverlap domain. Eight representative livestock variables were considered: 1) total hogs and pigs; 2) sows, gilts, and young gilts; 3) expected farrowings for the next quarter; 4) hogs purchased since June 1, 1983 now on hand; 5) total cattle and calves; 6) milk cows; 7) steers and heifers weighing 500 pounds or more, not for replacement; and 8) calves born since January 1, 1983.

NATURE OF THE NONRESPONDENTS

Several important characteristics of the nonrespondents as they relate to the test procedures are illustrated in Table 1. Hereafter, reference to nonrespondents excludes those with reliable data.

Nonresponse rates for hogs and cattle ranged from about 6 percent in Ohio to 16 percent in Kansas. This is similar to the JES results.

Table 1 also shows that nearly one-half of the hog nonrespondents and about 40 percent of the cattle nonrespondents at the six state level were classified as unknown as to specie presence. JES results were again similar. This unknown category is important to Procedure 2 since the proportion of these having livestock must be estimated. Crank (2) considered several estimators for this proportion and found varying results as the number in this category changed. The variability of the percent unknown by state suggests that with better training the overall size of this category could be reduced.

Table 1: PERCENTAGE ALL OF OPERATIONS CODED "NON-RESPONDENT" and PERCENTAGE OF NON-RESPONDENTS WITH LIVESTOCK PRESENCE INDICATOR CODED "UNKNOWN", 1983 December Enumerative Survey, by state.

	HOGS		CATTLE	
STATE	Nonrespondent %	Nonrespondents % Unknown	Nonrespondent %	Nonrespondents % Unknown
Georgia	10.6	66.1	10.1	44.6
Illinois	8.5	13.3	7.3	25.3
Iowa	10.7	52.1	10.4	43.2
Kansas	16.0	55.2	16.4	32.9
Ohio	6.4	66.0	5.7	70.2
Wyoming	-	-	19.2	52.6
Six States	10.4	48.0	10.5	40.6

Table 2 illustrates the difference between respondents and known nonrespondents in terms of the percentage having livestock. For both hogs and cattle, this percentage was much larger for known nonrespondents, the single exception being Ohio cattle. This concurs with previous research and is evidence against the validity of Procedure 1.

Table 2: PERCENTAGE OF ALL RESPONDENTS AND KNOWN NONRESPONDENTS HAVING LIVESTOCK, 1983 December Enumerative Survey, by state.

STATE	WITH HOGS		WITH CATTLE	
	Respondents	Known Nonrespondents	Respondents	Known Nonrespondents
Georgia	29.0	55.0	68.6	77.4
Illinois	30.4	64.4	49.9	71.7
Iowa	45.7	75.3	58.4	83.1
Kansas	15.7	34.4	73.2	83.0
Ohio	24.4	33.3	58.9	42.9
Wyoming	--	--	42.5	77.8
Six States	29.5	57.2	59.3	78.1

COMPARISONS OF PROCEDURES-- ENTIRE AREA FRAME

Tables 3-6 compare the area frame contributions to the farm and weighted estimates for the selected variables. Combined state totals are compared. Data for individual states are given in Appendices B and C.

Tables 3 and 4 display relative differences between the operational and test procedures and their associated significance levels from paired t-tests. Discussion follows Table 4.

Table 3: RELATIVE DIFFERENCES and SIGNIFICANCE LEVELS, FARM ESTIMATES, five-state hog totals, six-state cattle totals, 1983 DES.
Relative Difference = 100% (Test - Operational)/Operational.

Variable	Procedure 1		Procedure 2	
	Relative Difference	Significance Level	Relative Difference	Significance Level
Total Hogs	1.2	#	3.9	.17
Sows	0.4	#	2.9	.33
Hogs Purchased	8.4	.01	10.7	.01
Exp. Farrowings	0.0	#	2.7	.45
Total Cattle	-0.1	#	1.5	.44
Milk Cows	-0.5	#	0.8	#
Steers/Heifers	-5.6	.29	-3.9	.46
Calves Born	1.3	.45	2.9	.11

- significance level exceeds .50.

Table 4: RELATIVE DIFFERENCES and SIGNIFICANCE LEVELS, WEIGHTED ESTIMATES, five-state totals, 1983 DES.
Relative Difference = 100% (Test - Operational)/Operational.

Variable	Procedure 1		Procedure 2	
	Relative Difference	Significance Level	Relative Difference	Significance Level
Total Hogs	1.1	#	3.4	.20
Sows	1.3	#	3.6	.17
Hogs Purchased	9.2	.01	11.0	.01
Exp. Farrowings	1.4	#	3.7	.21
Total Cattle	-1.0	#	0.6	#
Milk Cows	2.4	.19	3.1	.09
Steers/Heifers	-9.3	.12	-7.6	.20
Calves Born	1.0	.47	2.5	.07

- significance level exceeds .50.

With two exceptions, estimates from Procedure 1 tended to be very near the operational indicating that, within a summary stratum, statisticians overall imputed approximately the stratum average of reported data for nonrespondents. Review of means for reported versus imputed data for weighted estimates showed considerable variation between summary strata indicating that stats probably did not actually use the stratum designation when imputing. Prior research (1) indicated that most livestock imputation is based on enumerator notes.

The two variables for which Procedure 1 differed most from the operational were hogs purchased which was significantly above the operational (at the 10% level) and weighted steers and heifers which was nearly significantly below. For purchases, states consistently imputed fewer hogs than respondents reported. The number of hogs purchased is a difficult item to impute, and basing this estimate on relationships for respondents is most likely an improvement over the operational procedure. This same relationship for hogs purchased was found in the JES (3). It is noteworthy that "hogs purchased" is used only as an editing tool and not actually estimated by the Board.

Procedure 1 estimates for steers and heifers were lower than the operational. Only in Iowa was this true and in Iowa the Procedure 1 weighted estimate was 23 percent less than the operational. This large difference was due to the operational imputation of a large number of steers/heifers for non-EO tracts. For example, the mean for imputed data in stratum 3 was 208 compared to only 12 for reported data. The largest of these was 1500 head imputed for one non-EO tract. However, a number of other tracts also contributed to this difference. If the one Iowa tract were deleted, the 5-state weighted difference would be reduced from -9.3% to -4.6%.

The imputation of 1500 steers and heifers in Iowa was based on an enumerator's conversation with an outside source presumed to be knowledgeable. Thus, this report might have been more appropriately coded as a "nonrespondent with reliable information" in which case the data would have been accepted by Procedures 1 and 2. Survey instructions need to be more precise in the use of this category. The more important point for now is that statisticians found out about this unusual situation. Even if an automated procedure were adopted statisticians and enumerators must not become less strident in their quest to get reliable information for as many of the sampled units as possible.

Procedure 2 estimates were consistently higher than Procedure 1 as should be expected. Procedure 2 was based on a classification of nonrespondents into categories involving specie presence and, as Table 2 showed, a larger percentage of nonrespondents had hogs and cattle than did respondents.

The discussion above concerning the differences between the operational and Procedure 1 estimates of hogs purchased and steers and heifers also applies to Procedure 2. In the case of steers and heifers, removing the one Iowa tract changed the weighted estimate difference for Procedure 2 for the 5 state total from -7.6% to -2.9%.

Procedure 2 estimates of calves born are significantly different or nearly so (at the 10% level) from the operational. Also, the Procedure 2 weighted estimate for milk cows is significantly higher. The difference in both cases is primarily due to Ohio. Ohio statisticians imputed, on the average, fewer head for nonrespondents than was reported by respondents. This is in contrast to the other states where average imputed values were larger than the reported.

These differences in amounts imputed by the States support the need for a more consistent and objective procedure for handling nonresponse.

Another factor contributing to the differences between the operational and Procedure 2 was the proportion of "unknowns" that were estimated to have livestock. Under Procedure 2 this proportion was estimated by using respondents and known nonrespondents and was considerably larger than under the operational procedure. For hogs, the proportion at the five-state level for Procedure 2 was 31.1%, but operationally only 8.1% of the unknowns had positive hogs imputed. For cattle the two proportions were 60.2% and 24.4%. Thus, Procedure 2 tended to give larger estimates than the operational because of this factor alone.

Whether stats were too conservative in imputing livestock for this category or, in fact, unknowns were not like the rest of the sample could not be discerned. However as mentioned earlier, more emphasis in enumerator training could likely reduce the size and thus the impact of this category.

Table 5 shows the results of multivariate paired t-tests for farm and weighted estimates comparing each pair of procedures. The multivariate test is described in Appendix E. Discussion follows the table.

Table 5: SIGNIFICANCE LEVELS, multivariate paired t-tests, farm and weighted estimates, combined five or six state totals, 1983 DES.

	FARM		WEIGHTED	
	Hogs	Cattle	Hogs	Cattle
Operational vs. Procedure 1	.16	.24	.01	.02
Operational vs. Procedure 2	.05	.11	.01	.01
Procedure 1 vs. Procedure 2	.01	.01	.01	.01

Weighted hog estimates under both Procedure 1 and 2 and farm hogs under Procedure 2 differed significantly from the operational due primarily to the "hogs purchased" variable. Procedure 1 and 2 weighted cattle estimates also showed significant differences from the operational, while the Procedure 2 farm estimate was nearly so. The lower estimates for steers and heifers found only in Iowa, and the calves born and milk cow variables previously discussed contributed to these differences. Procedure 1 always differed significantly from Procedure 2 due to the basic differences in underlying assumptions.

Table 6 shows the coefficient of variation for farm and weighted estimates of each variable at the combined state level. Estimates and CV's for individual states are shown in Appendices B and C. Variance formulas are in Appendix A.

Table 6: COEFFICIENTS OF VARIATION, farm and weighted estimates, combined five or six state totals, 1983 DES.

Variable	FARM			WEIGHTED		
	Operational	Procedure 1	Procedure 2	Operational	Procedure 1	Procedure 2
Total Hogs	8.1	7.8	7.5	5.9	6.3	6.1
Sows	9.3	9.4	9.1	6.7	7.2	7.1
Hogs Purchased	16.7	16.8	16.8	11.7	11.9	11.8
Exp. Farrowings	10.2	10.4	10.2	7.5	8.1	7.9
Total Cattle	5.6	5.5	5.4	3.7	3.7	3.6
Milk Cows	10.0	10.2	10.2	6.7	7.0	6.9
Steers/Heifers	11.0	11.2	11.2	8.7	7.9	7.9
Calves Born	6.4	6.6	6.6	3.6	3.9	3.8

As Table 6 shows, coefficients of variation under both test procedures are quite close to those for the operational procedure with a general tendency to be slightly higher. Of course as Dillard and Ford (3) point out, the operational procedure summarized imputed data as though it were reported, and thus largely ignored the imprecision due to nonresponse.

COMPARISONS OF PROCEDURES— NONOVERLAP DOMAIN

Appendix D shows estimates, CV's, and univariate t-test results, by state, for the weighted nonoverlap domain. The results of multivariate tests on both farm and weighted estimates were similiar to those for the entire area frame excluding EO's. Specifically, as a group hog estimates under both test procedures differed significantly from the operational. Also, differences for cattle variables were nearly significant with the exception of the Procedure 1 farm estimator.

Relative differences between the operational and the two test procedures are shown below in Table 7 for farm and weighted estimates. It should be noted that although farm estimates are shown, only weighted NOL estimates are used in these states.

Table 7: RELATIVE DIFFERENCES, NONOVERLAP DOMAIN, farm and weighted estimates, combined five or six state totals, 1983 DES.
RELATIVE DIFFERENCE = 100% (Test - Operational)/Operational.

Variable	**Procedure 1**		**Procedure 2**	
	Farm	Weighted	Farm	Weighted
Total Hogs	4.3	4.5	7.6	7.0
Sows	2.9	4.7	5.9	6.6
Hogs Purchased	10.4	10.5	13.6	12.5
Exp. Farrowings	-0.2	5.9	1.6	7.7
Total Cattle	0.4	3.0	2.5	4.3
Milk Cows	0.2	2.1	0.1	2.6
Steers/Heifers	4.3	3.7	7.4	5.7
Calves Born	-2.7	0.9	-1.5	2.0

Relative differences between the operational and test procedures were generally larger for the NOL domain, particularly for hog variables. Stats may have been too conservative in imputing for NOL tracts where less may have been known about the operations. An alternative is that NOL nonrespondents truly had fewer livestock than NOL respondents. However, analysis indicated, as for the non-EO domain, that a larger proportion of NOL nonrespondents had hogs/cattle than did NOL respondents.

"Hogs purchased" still showed the largest discrepency with the operational procedure. The lower test estimates for steers/heifers did not occur in the NOL domain as the large imputed values in Iowa were for overlap tracts.

It should be kept in mind that the NOL estimates contribute only to the multiple frame (MF) estimators. In the 1983 DES, the NOL estimate for the combined test states was about 23 percent of the total MF direct expansion for hogs and 22 percent for cattle.

CONCLUSIONS

• Procedure 2, the automated adjustment which incorporated the classification of nonrespondents as to specie presence, was found to be an acceptable alternative to the operational procedure for the DES. In most cases Procedure 2 gave higher estimates but when the differences were significant, the variables involved, such as hogs purchased, were items that were difficult to impute and were therefore likely to be underestimated by the operational procedure.

• Procedure 2 is analagous to that recommended in the JES study and to that in place for list frame surveys of hogs and cattle.

• The objectivity of this procedure removes the state to state variability in handling nonresponse. While some states may be doing an excellent job, the overall effect of imputation on the estimates is difficult to measure currently. An automated procedure also eliminates what is currently a time consuming step in conducting the survey.

• Procedure 2 makes use of all available information. It allows imputation of data when reliable information is known.

• The classification of nonrespondents by specie presence is important to procedure 2. This classification needs to be handled more consistently across states and, in particular, the size of the unknown group needs to be reduced.

• As the JES study (3) points out, no automated procedure can replace the need for well-trained and dedicated field enumerators securing accurate data for as large a portion of the sample as possible. Enumerator training must continue to stress this.

• If an automated method such as Procedure 2 were adopted for the JES, consideration would have to be given to the methodology in classifying nonrespondents into select and summary strata for the DES. However, it seems this would have minimal impact as long as specie presence at least was known.

• Finally, if Procedure 2 estimates were calculated operationally the possibility of a summary stratum having no respondents with livestock but having one or more nonresondents with livestock would have to be addressed. In this case, collasping of strata would be necessary in order to have data on which to base imputation for such nonrespondents. This possibility increases for minor livestock states.

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APPENDIX A

This appendix describes the estimators and variance calculations for the operational and two test procedures considered in this report. The description applies to each of the eight hog and cattle variables. Farm and weighted values are described first and then their use is incorporated into the description of the three procedures.

1. Farm and Weighted Values:

For each operation in the domain of interest (non-EO or nonoverlap):

a) The Farm Value for a variable is the total number of head on the entire farm if the operator lives inside the tract, i.e. is a resident agricultural operator (RAO). The farm value is zero if the operator lives outside.

b) The Weighted Value for a variable is the product of the ratio of tract acreage to entire farm acreage and the number of head on the entire farm. Suppose for example that a farmer had 150 hogs located on his entire farm, both inside and outside the tract. Suppose further that he had 400 acres of all land, of which 100 acres were inside the tract. His weighted hog value would be:

$$(100/400)\ 150 = 37.5$$

Note that this is regardless of whether or not he was a RAO.

2. Estimators and Variances

Formulas are given for farm estimators. For weighted, replace farm value by weighted value and RAO's by all farm operators in the domain of interest.

Notation:

x_{ih} = farm value for tract i in summary stratum h.

EF_i = DES expansion factor for tract i = (DES sampling interval)(JES expansion factor)

EF_j = JES expansion factor for segment j

v_h = number of DES tracts in stratum h

n_h = number of RAO's in stratum h

$n1_h$ = number of RAO's in stratum h with "good" data-includes both respondents and nonrespondents with reliable information

$n4_h$ = number of nonrespondent RAO's in stratum h coded as having a positive number of hogs/cattle

$n6_h$ = number of nonrespondent RAO's in stratum h coded as unknown as to hogs/cattle presence

m_h = number of RAO's in stratum h with "good" data having positive hogs/cattle.

t_{jh} = number of JES tracts in segment j in summary stratum h

$T_h = \sum_j (EF_j)(t_{jh})$ = expanded number of JES tracts in stratum h

(a) <u>Operational Estimator and Variance</u> see Hartley (6), Specifications (8)

$\hat{X}$ = estimated total

$= \sum_h \hat{X}_h$, where $\hat{X}_h$ = estimated total for stratum h

$= \sum_h \sum_i EF_i \, x_{ih}$

var $(\hat{X})$ = estimated variance of $\hat{X}$

$= var_1 (\hat{X}) + var_2 (\hat{X})$

where $var_1 (\hat{X})$ is the between tract within summary stratum component of the variance

and $var_2 (\hat{X})$ is a between segment within JES district component of the variance due to the subsampling design of the DES.

$var_1 (\hat{X}) = \sum_h var_1 (\hat{X}_h)$

$$\text{where } var_1 (\hat{X}_h) = \left(\frac{T_h - v_h}{T_h}\right)\left(\frac{v_h}{v_h - 1}\right) \sum_i \left[(EF_i \, x_{ih})^2 - \hat{X}_h^2/v_h\right]$$

Additional notation:

t_{jhD} = number of JES tracts in segment j, District D, in stratum h

${}_sN_D = \sum_j EF_{jD}$ = expanded number of segments in District D

${}_sn_D$ = number of JES segments in District D

$\bar{x}_h = \sum_i EF_i \, x_{ih} / \sum_i EF_i$ = weighted stratum mean for stratum h

$T_{xjD} = \sum_h t_{jhD} \, \bar{x}_h$ = generated segment total for segment j, District D

Then, $var_2 (\hat{X}) = \sum_D var_2 (\hat{X}_D)$

$$\text{where } var_2 (\hat{X}_D) = \left(\frac{{}_sN_D - {}_sn_D}{{}_sN_D}\right)\left(\frac{{}_sn_D}{{}_sn_D - 1}\right)\left[\sum_j (EF_j \, T_{xjD})^2 - \frac{(\sum EF_j \, T_{xjD})^2}{{}_sn_D}\right]$$

Thus, $var_2 (\hat{X})$ is a measure of the variabilitiy of the proportional representation of summary strata from segment to segment. A second source of variation, the per-tract item for tracts in the same summary stratum, is assumed to be a constant, i.e. the weighted stratum mean from the DES.

Across the eight variables, at the combined state level, this between segment component accounted for between 2 and 9 percent of the total variance for the farm estimator and between 4 and 17 percent for the weighted.

(b) Procedure 1 Estimator and Variance

notation: $x1_{ih}$ = farm value for "good" RAO tract i in stratum h ($n1_h$ such tracts)

$\hat{X}_h$ = estimated total for stratum h

$$= (\sum_i EF_i \, x1_{ih}) \, (n_h / n1_h)$$

$$= X1_h \, R_h, \text{ where } X1_h = \sum_i EF_i \, x1_{ih} \text{ and } R_h = n_h / n1_h$$

$$\hat{X} = \sum_h \hat{X}_h = \text{estimated total}$$

$$var(\hat{X}) = \text{estimated variance of } \hat{X}$$

$$= var_1(\hat{X}) + var_2(\hat{X})$$

$$var_1(\hat{X}) = \underset{h}{\;} var_1(\hat{X}_h)$$

$$\text{where } var_1(\hat{X}_h) = var_1(X1_h \, R_h)$$

$$= \hat{R}_h^2 \, var_1(X1_h) + X1_h^2 \, var_1(R_h)$$

The latter result corresponds to Eq. 9.5 in Hansen Hurwitz, Madow (5) except the covariance term is dropped and sample estimates replace population values. It also corresponds to Crank's (2) approximation.

$$\text{Now, } var_1(X1_h) = \left(\frac{T_h - n1_h}{T_h}\right)\left(\frac{n1_h - 1}{n1_h}\right)\left[\sum_i (EF_i \cdot x1_{ih})^2 - \frac{(\sum_i EF_i \cdot x1_{ih})^2}{n1_h}\right]$$

$$\text{and } var_1(R_h) = \left(\frac{T_h - n_h}{T_h}\right)\left[1 - (n1_h/n_h)\right] \Big/ \left[(n1_h/n_h)^3 \quad (n_h - 1)\right]$$

$var_2(\hat{X})$ is calculated as for the operational estimator with x_{ih} replaced by $x1_{ih}R_h$ for "good" tracts and replaced by zero for nonrespondent without reliable data.

(c) Procedure 2 Estimator and Variance

notation: $y1_{ih}$ = farm value for "good" RAO tract i in stratum h with positive hogs/cattle.

As for Procedure 1, $X1_h = EF_i \, x1_{ih}$

$$\hat{X}_h = \text{estimated total for stratum } h$$

$$= n_h \cdot \frac{X1_h}{m_h} \cdot \frac{m_h + n4_h}{n_h - n6_h}$$

$$= n_h \cdot \frac{X1_h}{m_h} \cdot P_h, \quad P_h = \frac{m_h + n4_h}{n_h - n6_h} = \text{estimated proportion of operations with positive livestock}$$

Then, $\hat{X} = \sum_h \hat{X}_h$ = estimated total

var $(\hat{X})$ = estimated variance of $\hat{X}$

$$= \text{var}_1 (\hat{X}) + \text{var}_2 (\hat{X})$$

and $\text{var}_1 (\hat{X}) = \sum_h \text{var}_1 (\hat{X}_h)$

where $\text{var}_1 (\hat{X}_h) = \text{var}_1 \left[n_h \frac{X1_h}{m_h} \cdot P_h \right]$

$$= \left[n_h^2 \; P_h^2 \; \text{var}_1 \left(\frac{X1_h}{m_h} \right) + \left(\frac{X1_h}{m_h} \right)^2 \text{var}_1 (P_h) \right] \qquad (5)$$

$$\text{var}_1 \left(\frac{X1_h}{m_h} \right) = \left(\frac{T_h - m_h}{T_h} \right) \frac{1}{m_h (m_h - 1)} \left[\sum_1 (EF_i \cdot y1_{ih})^2 - \left(\sum_1 EF_i \cdot y1_{ih} \right)^2 / m_h \right]$$

and, $$\text{var}_1 (P_h) = \left[\frac{T_h - (n_h - n6_h)}{T_h} \right] \left[P_h (1 - P_h) / (n_h - n6_h - 1) \right]$$

Also, $\text{var}_2 (\hat{X})$ is calculated as for the operational estimator with x_{ih} replaced by $x1_{ih} (n_h/m_h) P_h$ for "good" tracts and by zero for nonrespondents without reliable data.

NOTE: The above variance calculations for the test procedures treat n_h, the number of RAO tracts in stratum h, as though it were without sampling variability. Actually this value depends on two sampling characteristics - being a farm operator and being a resident tract operator. Thus, these variance estimates tend to under estimate slightly the true variance. Operationally, the proportion of farm tracts that are RAO's is also treated as a population value.

APPENDIX B

AREA FARM ESTIMATES AND TEST RESULTS

Table B1: AREA FARM ESTIMATES AND COEFFICIENTS OF VARIATION, by state, 1983 DES, excluding EO's.

State	Operational		Procedure 1		Procedure 2	
	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)
			TOTAL HOGS			
Georgia	779	20.6	805	18.3	770	18.1
Illinois	5,942	17.2	5,965	17.0	6,149	17.0
Iowa	13,840	10.8	14,155	10.2	14,513	9.6
Kansas	1,154	21.3	992	24.1	1,093	24.3
Ohio	1,215	19.1	1,307	18.6	1,300	18.6
Five States	22,931	8.1	23,224	7.8	23,824	7.5
			SOWS			
Georgia	105	25.3	97	19.8	93	19.7
Illinois	692	18.4	689	18.2	708	18.1
Iowa	1,878	12.8	1,926	12.8	1,976	12.3
Kansas	156	24.8	118	24.6	131	24.3
Ohio	166	20.4	179	20.0	178	20.1
Five States	2,998	9.3	3,008	9.3	3,086	9.1

AREA FARM ESTIMATES AND TEST RESULTS

State	Operational		Procedure 1		Procedure 2	
	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)
HOGS PURCHASED						
Georgia	46	65.8	48	67.3	46	67.9
Illinois	414	34.5	437	35.5	450	36.4
Iowa	1,462	23.0	1,629	22.7	1,669	22,6
Kansas	244	39.1	235	41.6	238	40.4
Ohio	127	34.8	135	34.7	134	35.4
Five States	2,292	16.7	2,484	16.8	2,537	16.8
EXPECTED FARROWINGS						
Georgia	43	37.4	33	26.2	31	26.4
Illinois	262	20.6	258	20.8	267	20.7
Iowa	806	13.7	820	13.9	842	13.5
Kansas	52	29.9	47	28.3	51	28.5
Ohio	76	23.6	81	23.4	81	23.5
Five States	1,239	10.2	1,239	10.4	1,272	10.2
TOTAL CATTLE						
Georgia	1,530	12.8	1,480	11.8	1,493	11.5
Illinois	3,012	12.5	3,032	12.0	3,066	11.9
Iowa	5,157	10.4	4,848	10.3	4,981	10.0
Kansas	4,523	12.7	4,788	11.9	4,833	11.6
Ohio	1,811	11.9	1,835	11.4	1,837	11.3
Wyoming	897	28.6	935	31.9	977	32.1
Six States	16,929	5.6	16,920	5.5	17,187	5.4

AREA FARM ESTIMATES AND TEST RESULTS

State	Operational		Procedure 1		Procedure 2	
	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)
MILK COWS						
Georgia	74	45.1	50	57.3	51	57.2
Illinois	321	21.7	322	22.5	329	22.6
Iowa	378	17.6	375	18.2	385	18.0
Kansas	145	29.5	149	31.2	151	31.1
Ohio	473	17.8	487	17.3	487	17.3
Wyoming	5	49.3	6	69.6	5	62.6
Six States	1,396	10.0	1,389	10.2	1,408	10.2
STEERS AND HEIFERS						
Georgia	146	36.1	144	37.7	145	37.8
Illinois	1,065	25.1	1,118	25.2	1,129	25.3
Iowa	1,804	17.9	1,448	18.1	1,492	18.1
Kansas	1,058	21.8	1,126	22.3	1,142	22.2
Ohio	361	25.0	349	27.9	350	27.9
Wyoming	25	52.9	26	63.6	27	64.2
Six States	4,460	11.0	4,211	11.2	4,286	11.2
CALVES BORN						
Georgia	675	14.0	635	13.3	640	13.2
Illinois	903	12.9	903	12.5	914	12.4
Iowa	1,553	11.4	1,563	11.6	1,603	11.3
Kansas	1,591	14.7	1,649	14.4	1,664	14.2
Ohio	635	13.4	656	12.7	656	12.6
Wyoming	499	33.0	527	36.7	552	37.1
Six States	5,857	6.4	5,933	6.6	6,028	6.6

AREA FARM ESTIMATES AND TEST RESULTS

Table B2: RELATIVE DIFFERENCE and SIGNIFICANCE LEVEL, area farm estimates, by state, 1983 DES, excluding EO's.
Relative difference =100% (test estimate - operational estimate)/operational estimate.

State	Procedure 1 Relative difference (%)	Procedure 1 Significance level	Procedure 2 Relative difference (%)	Procedure 2 Significance level
	TOTAL HOGS			
Georgia	3.3	#	-1.1	#
Illinois	0.4	#	3.5	#
Iowa	2.3	#	4.9	.18
Kansas	-14.1	.33	-5.3	#
Ohio	7.6	.01	6.9	.01
Five States	1.3	#	3.9	.17
	SOWS			
Georgia	-7.9	#	-11.8	#
Illinois	-0.5	#	2.3	#
Iowa	2.6	.46	5.2	.16
Kansas	-24.4	.22	-16.3	.43
Ohio	7.4	.01	6.9	.01
Five States	0.4	#	2.9	.33

significance level exceeds .50.

AREA FARM ESTIMATES AND TEST RESULTS

State	Procedure 1: Relative difference (%)	Procedure 1: Significance level	Procedure 2: Relative difference (%)	Procedure 2: Significance level
HOGS PURCHASED				
Georgia	6.2	.38	0.6	#
Illinois	5.7	.16	8.7	.16
Iowa	11.5	.01	14.2	.01
Kansas	-3.7	#	-2.6	#
Ohio	5.7	.02	5.6	.02
Five States	+8.4	.01	+10.7	.01
EXPECTED FARROWINGS				
Georgia	-23.6	.47	-26.9	.41
Illinois	-1.4	#	2.0	#
Iowa	1.7	#	4.5	.30
Kansas	-9.6	#	-2.7	#
Ohio	6.7	.02	6.2	.02
Five States	+0.03	#	+2.7	.45
TOTAL CATTLE				
Georgia	-3.2	.49	-2.4	#
Illinois	0.7	#	1.8	#
Iowa	-6.0	.23	-3.4	#
Kansas	5.9	.02	6.9	.01
Ohio	1.4	#	1.4	#
Wyoming	4.2	#	8.9	.35
Six States	0.1	#	+1.5	.44

AREA FARM ESTIMATES AND TEST RESULTS

State	Procedure 1 Relative difference (%)	Procedure 1 Significance level	Procedure 2 Relative difference (%)	Procedure 2 Significance level
MILK COWS				
Georgia	-32.1	.32	-31.9	.22
Illinois	0.3	#	2.3	#
Iowa	-0.7	#	2.0	#
Kansas	2.9	#	4.5	#
Ohio	2.9	.09	2.9	.09
Wyoming	10.0	#	2.0	#
Six States	-0.5	#	+0.8	#
STEERS AND HEIFERS				
Georgia	-1.9	#	-0.8	#
Illinois	5.0	.08	5.9	.06
Iowa	-19.7	.11	-17.3	.17
Kansas	6.4	.12	8.0	.08
Ohio	-3.2	#	-2.9	#
Wyoming	3.0	#	9.0	#
Six States	-5.6	.29	-3.9	.46
CALVES BORN				
Georgia	-5.9	.31	-5.2	.36
Illinios	0.0	#	1.3	#
Iowa	0.6	#	3.2	.39
Kansas	3.7	.31	4.6	.22
Ohio	3.2	.02	3.3	.02
Wyoming	5.6	.47	10.7	.30
Six States	+1.3	.45	+2.9	.11

APPENDIX C

AREA WEIGHTED ESTIMATES AND TEST RESULTS

Table C1: AREA WEIGHTED ESTIMATES AND COEFFICIENTS OF VARIATION, by state, 1983 DES, excluding EO's.

	Operational		Procedure 1		Procedure 2	
State	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)
TOTAL HOGS						
Georgia	878	16.2	899	17.9	900	17.7
Illinois	4,657	11.1	4,645	11.3	4,821	11.2
Iowa	14,611	8.1	14,717	8.7	14,972	8.5
Kansas	834	15.8	876	17.9	934	17.2
Ohio	1,423	12.7	1,521	13.5	1,528	13.4
Five States	22,403	5.9	22,659	6.3	23,155	6.1
SOWS						
Georgia	113	15.9	112	17.3	112	16.8
Illinois	592	13.0	586	13.7	609	13.8
Iowa	1,790	9.2	1,815	10.1	1,846	9.9
Kansas	110	19.1	117	21.3	126	20.9
Ohio	180	13.3	192	14.0	193	13.9
Five States	2,785	6.7	2,822	7.2	2,886	7.1

AREA WEIGHTED ESTIMATES AND TEST RESULTS

State	Operational		Procedure 1		Procedure 2	
	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)
HOGS PURCHASED						
Georgia	116	63.4	127	64.4	129	64.8
Illinois	395	21.8	429	21.8	442	21.7
Iowa	1,702	15.8	1,849	15.8	1,878	15.7
Kansas	236	34.5	273	37.4	278	36.6
Ohio	144	21.8	152	22.1	153	22.3
Five States	2,593	11.7	2,831	11.9	2,879	11.8
EXPECTED FARROWINGS						
Georgia	49	17.1	49	18.1	49	17.7
Illinois	240	13.7	235	14.1	244	14.1
Iowa	795	10.3	805	11.2	820	11.1
Kansas	50	25.3	57	27.5	61	26.6
Ohio	77	15.8	82	16.5	83	16.6
Five States	1,211	7.5	1,228	8.0	1,256	7.9
TOTAL CATTLE						
Georgia	1,467	8.3	1,469	8.7	1,486	8.6
Illinois	2,625	8.3	2,668	8.6	2,695	8.5
Iowa	5,315	7.6	4,784	6.7	4,916	6.5
Kansas	4,858	7.0	5,120	7.7	5,200	7.4
Ohio	1,819	7.2	1,885	7.3	1,875	7.3
Five States	16,084	3.7	15,925	3.7	16,173	3.6

AREA WEIGHTED ESTIMATES AND TEST RESULTS

State	Operational Estimate (000)	Operational CV (%)	Procedure 1 Estimate (000)	Procedure 1 CV (%)	Procedure 2 Estimate (000)	Procedure 2 CV (%)
MILK COWS						
Georgia	59	32.7	43	38.6	44	38.6
Illinois	278	14.5	287	14.9	289	14.8
Iowa	293	13.6	303	14.3	310	14.2
Kansas	97	18.4	99	20.5	100	20.4
Ohio	457	10.8	480	10.9	477	10.9
Five States	1,184	6.7	1,212	7.0	1,220	6.9
STEERS AND HEIFERS						
Georgia	110	16.9	112	17.7	114	17.7
Illinois	822	19.3	856	19.7	862	19.7
Iowa	2,090	14.6	1,600	11.0	1,650	10.9
Kansas	1,234	15.5	1,263	17.0	1,283	16.8
Ohio	336	16.7	335	17.4	333	17.4
Five States	4,592	8.7	4,167	7.9	4,242	7.9
CALVES BORN						
Georgia	617	8.6	602	8.9	608	8.8
Illinois	840	7.9	859	8.1	871	8.2
Iowa	1,562	7.9	1,526	8.3	1,565	8.1
Kansas	1,458	6.9	1,506	7.6	1,528	7.4
Ohio	663	8.0	695	8.0	693	8.0
Five States	5,139	3.6	5,188	3.9	5,265	3.8

Table C2: RELATIVE DIFFERENCE AND SIGNIFICANCE LEVEL, area weighted estimates, by state, 1983 DES, excluding EO's.
Relative difference =100% (test estimate - operational estimate) /operational estimate.

State	Procedure 1 Relative difference (%)	Procedure 1 Significance level	Procedure 2 Relative difference (%)	Procedure 2 Significance level
TOTAL HOGS				
Georgia	2.3	#	2.4	#
Illinois	-0.3	#	3.5	#
Iowa	0.7	#	2.5	.49
Kansas	5.1	#	12.1	.08
Ohio	6.9	.01	7.3	.01
Five States	1.1	#	3.4	.20
SOWS				
Georgia	-0.2	#	-0.5	#
Illinois	-1.0	#	2.9	#
Iowa	1.4	#	3.1	.38
Kansas	6.1	.38	14.4	.07
Ohio	6.6	.01	7.2	.01
Five States	1.3	#	3.6	.17

- significance level exceeds .50.

AREA WEIGHTED ESTIMATES AND TEST RESULTS

State	Procedure 1		Procedure 2	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level
HOGS PURCHASED				
Georgia	9.5	.19	11.2	.19
Illinois	8.7	.01	11.9	.01
Iowa	8.6	.07	10.3	.03
Kansas	15.5	.16	17.6	.10
Ohio	6.1	.02	6.4	.02
Five States	9.2	.01	11.0	.01
EXPECTED FARROWINGS				
Georgia	1.0	#	0.5	#
Illinois	-2.1	#	1.6	#
Iowa	1.2	#	3.1	.46
Kansas	13.2	.07	21.2	.01
Ohio	6.2	.03	6.7	.02
Five States	1.4	#	3.7	.21
TOTAL CATTLE				
Georgia	0.1	#	1.3	#
Illinois	1.6	.46	2.7	.25
Iowa	-10.0	.08	-7.5	.18
Kansas	5.4	.02	7.0	.01
Ohio	3.6	.01	3.1	.02
Five States	-1.0	#	0.6	#

AREA WEIGHTED ESTIMATES AND TEST RESULTS

State	Procedure 1		Procedure 2	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level
MILK COWS				
Georgia	-26.7	.18	-25.3	.20
Illinois	3.3	.34	4.1	.24
Iowa	3.3	.37	5.6	.14
Kansas	2.6	#	3.8	#
Ohio	4.9	.01	4.4	.01
Five States	2.4	.19	3.1	.09
STEERS AND HEIFERS				
Georgia	1.4	#	3.2	.49
Illinois	4.1	.03	4.9	.02
Iowa	-23.4	.07	-21.1	.10
Kansas	2.4	#	4.0	.36
Ohio	-0.1	#	-0.7	#
Five States	-9.3	.12	-7.6	.20
CALVES BORN				
Georgia	-2.4	.41	-1.4	#
Illinois	2.3	.27	3.8	.09
Iowa	-2.3	.47	0.2	#
Kansas	3.3	.19	4.9	.07
Ohio	4.9	.01	4.5	.01
Five States	1.0	.47	2.5	.07

APPENDIX D

AREA WEIGHTED NONOVERLAP ESTIMATES AND TEST RESULTS

Table D1: AREA WEIGHTED NONOVERLAP ESTIMATES AND COEFFICIENTS OF VARIATION, by state, 1983 DES.

State	Operational		Procedure 1		Procedure 2	
	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)
TOTAL HOGS						
Georgia	448	25.7	469	30.6	474	30.8
Illinois	1,242	19.2	1,295	19.8	1,343	20.2
Iowa	3,048	17.8	3,217	19.1	3,297	18.6
Kansas	238	27.0	226	30.0	232	30.1
Ohio	713	17.2	740	17.4	743	17.5
Five States	5,689	10.9	5,946	11.7	6,088	11.5
SOWS						
Georgia	59	24.7	58	30.6	58	30.4
Illinois	167	19.3	173	20.0	179	20.3
Iowa	403	17.6	432	18.7	439	18.2
Kansas	33	28.7	31	32.1	31	31.8
Ohio	97	17.7	101	17.9	101	17.9
Five State	759	10.7	795	11.6	809	11.4

AREA WEIGHTED NONOVERLAP ESTIMATES AND TEST RESULTS

State	Operational Estimate (000)	Operational CV (%)	Procedure 1 Estimate (000)	Procedure 1 CV (%)	Procedure 2 Estimate (000)	Procedure 2 CV (%)
HOGS PURCHASED						
Georgia	88	81.6	97	82.7	99	83.1
Illinois	177	33.0	188	33.1	192	32.8
Iowa	503	32.1	566	30.9	577	30.6
Kansas	25	56.3	28	59.3	28	60.2
Ohio	61	27.5	65	29.0	65	29.6
Five States	854	21.9	944	21.6	960	21.5
EXPECTED FARROWINGS						
Georgia	27	25.5	26	30.4	27	30.4
Illinois	77	23.6	80	24.3	82	24.5
Iowa	153	23.4	167	25.3	169	24.9
Kansas	11	34.2	12	36.7	13	36.4
Ohio	42	21.6	43	21.8	43	22.0
Five States	310	13.5	328	14.7	334	14.5
TOTAL CATTLE						
Georgia	562	11.4	555	11.1	557	11.0
Illinois	440	13.4	450	14.0	456	14.3
Iowa	965	11.9	950	12.3	986	11.7
Kansas	1,315	14.1	1,434	14.3	1,440	14.1
Ohio	572	10.7	582	10.6	582	10.4
Five States	3,854	6.3	3,970	6.5	4,021	6.4

AREA WEIGHTED NONOVERLAP ESTIMATES AND TEST RESULTS

State	Operational		Procedure 1		Procedure 2	
	Estimate (000)	CV (%)	Estimate (000)	CV (%)	Estimate (000)	CV (%)
MILK COWS						
Georgia	28	53.1	20	61.0	20	61.2
Illinois	67	32.2	67	32.3	67	32.2
Iowa	37	34.0	40	33.4	42	33.2
Kansas	9	40.5	12	41.5	12	41.2
Ohio	86	21.4	92	21.9	92	21.8
Five States	226	15.2	231	15.2	232	15.1
STEERS AND HEIFERS						
Georgia	38	25.8	40	25.4	40	25.4
Illinois	84	19.8	91	21.2	92	21.9
Iowa	276	20.7	264	24.1	278	24.3
Kansas	427	26.4	471	27.7	474	27.6
Ohio	131	24.7	125	24.7	125	24.7
Five States	956	13.8	991	15.1	1,010	15.1
CALVES BORN						
Georgia	237	12.8	224	12.4	225	12.3
Illinois	159	16.0	158	15.8	160	15.7
Iowa	377	21.5	378	22.6	390	22.4
Kansas	385	14.5	402	15.0	403	14.8
Ohio	193	11.6	200	11.3	201	11.2
Five States	1,351	8.0	1,362	8.3	1,378	8.3

AREA WEIGHTED NONOVERLAP ESTIMATES AND TEST RESULTS

Table D2: RELATIVE DIFFERENCE AND SIGNIFICANCE LEVEL, area weighted nonoverlap estimates, by state, 1983 DES.
Relative difference is 100% (test estimate - operational estimate) / operational estimate.

State	Procedure 1		Procedure 2	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level
TOTAL HOGS				
Georgia	4.6	#	5.7	#
Illinois	4.2	.11	8.1	.03
Iowa	5.5	.23	8.2	.10
Kansas	-5.2	#	-2.7	#
Ohio	3.8	.22	4.2	.16
Five States	4.5	.11	7.0	.02
SOWS				
Georgia	-1.0	#	-0.2	#
Illinois	3.6	.18	7.4	.05
Iowa	7.1	.16	8.7	.09
Kansas	-6.3	#	-4.0	#
Ohio	3.7	.16	4.5	.09
Five States	4.7	.14	6.6	.04

- significance level exceeds .50.

AREA WEIGHTED NONOVERLAP ESTIMATES AND TEST RESULTS

State	Procedure 1		Procedure 2	
	Relative difference (%)	Significance level	Relative difference (%)	Significance level
HOGS PURCHASED				
Georgia	10.9	.29	13.6	.29
Illinois	6.2	.03	8.2	.01
Iowa	12.5	.01	14.7	.01
Kansas	9.8	.40	8.9	.46
Ohio	7.0	.21	6.7	.18
Five States	10.5	.01	12.5	.01
EXPECTED FARROWINGS				
Georgia	-3.0	#	-2.2	#
Illinois	4.0	.16	7.3	#
Iowa	8.7	.17	10.1	#
Kansas	12.8	.26	15.9	.01
Ohio	3.5	.27	4.2	.47
Five States	5.9	.11	7.7	.04
TOTAL CATTLE				
Georgia	-1.2	#	-0.9	#
Illinois	2.3	#	3.6	#
Iowa	-1.6	#	2.2	#
Kansas	9.0	.01	9.5	.01
Ohio	1.7	.50	1.8	.47
Five States	3.0	.11	4.3	.03

AREA WEIGHTED NONOVERLAP ESTIMATES AND TEST RESULTS

State	Procedure 1 Relative difference (%)	Procedure 1 Significance level	Procedure 2 Relative difference (%)	Procedure 2 Significance level
MILK COWS				
Georgia	-27.3	.41	-26.7	.42
Illinois	0.5	#	0.2	#
Iowa	10.3	.01	14.1	.01
Kansas	25.7	.04	24.6	.03
Ohio	6.7	.03	6.6	.02
Five States	2.1	#	2.6	#
STEERS AND HEIFERS				
Georgia	4.7	.06	5.0	.05
Illinois	8.4	.17	9.9	.20
Iowa	-4.2	#	0.7	#
Kansas	10.2	.08	11.1	.06
Ohio	-4.4	#	-4.3	#
Five States	3.7	.36	5.7	.19
CALVES BORN				
Georgia	-5.7	.36	-5.3	.38
Illinois	-0.1	#	0.6	#
Iowa	0.4	#	3.6	.40
Kansas	4.4	.35	4.7	.31
Ohio	3.6	.01	3.8	.01
Five States	0.9	#	2.0	.35

APPENDIX E

This appendix describes the univariate and multivariate test statistics used in the analyses.

The analysis used paired t-tests to calculate the univariate test statistics. Formulas are analagous to those used by Nealon (7).

Suppose $\hat{Y}$ and $\hat{Z}$ are estimated totals for a particular item using two different estimators. Suppose

$$\hat{Y} = \sum_{h=1}^{8} \sum_{i=1}^{v_h} EF_i \, y_{ih} \quad \text{and} \quad \hat{Z} = \sum_{h=1}^{8} \sum_{i=1}^{v_h} EF_i \, z_{ih}$$

where

y_{ih} = value for tract i, summary stratum h, using the first estimator

z_{ih} = value for tract i, summary stratum h, using the second estimator

EF_i = DES expansion factor for tract i

v_h = number of tracts in stratum h

Let $\hat{D} = \hat{Y} - \hat{Z}$ be the difference between the estimated totals

Then $\hat{D} = \sum_{h=1}^{8} \sum_{i=1}^{v_h} EF_i \, d_{ih}$, where $d_{ih} = y_{ih} - z_{ih}$

$\text{var}(\hat{D})$ = estimated variance of $\hat{D}$

$= \text{var}_1(\hat{D}) + \text{var}_2(\hat{D})$

These two components are described in Appendix A. Calculations are analagous to those for the operational variance.

If D = Y - Z is the population difference between the totals using estimators Y and Z, then to test

$$H_O : D = 0 \quad \text{vs} \quad H_A : D \neq 0$$

compute $t = \dfrac{\hat{D}}{\sqrt{\text{var}(\hat{D})}}$ and reject if t is too large in absolute value

The multivariate tests are generalizations of the univariate tests. This analysis used Hotelling's multivariate test (9).

Suppose one calculates $\hat{Y}$ and $\hat{Z}$ as above for q items of interest using the same two estimators each time.

Let $\hat{D}_1, \ldots, \hat{D}_q$ be the differences, $\hat{Y} - \hat{Z}$, for the q items.

Form the q x 1 column vector $\hat{D} = (\hat{D}_1, \ldots, \hat{D}_q)^T$.

Let W be the variance-covariance matrix of D where variance estimates form the main diagonal and covariance estimates form the off-diagonal entries.

Specifically,

$$\text{cov}\ (\hat{D}_\ell, \hat{D}_m) = \sum_{h=1}^{8} \sum_{i=1}^{v_h} \left(\frac{T_h - v_h}{T_h}\right)\left(\frac{v_h}{v_h - 1}\right) \left[d'_{\ell(ih)} - d'_{\ell(.h)}\right]\left[d'_{m(ih)} - d'_{m(.h)}\right]$$

If W_{ij} is the entry in row i and column j in W,

then $W_{ii} = \text{var}\ (\hat{D}_i) \quad i = 1, \ldots, q$

and $W_{ij} = W_{ji} = \text{cov}\ (\hat{D}_i, \hat{D}_j) \quad i = 1, \ldots, q;\ j = 1, \ldots, q\ (i \neq j)$

Thus W is a q x q symmetric matrix

To test H_0: D is a zero vector

vs

H_A: at least one component of D is non-zero

compute $t^2 = \hat{D}^T W^{-1} \hat{D}$

Let

$$F = \left(\frac{v. - 8 - q + 1}{(v. - 8)\ q}\right) t^2$$

where $v. = \sum_{h=i}^{8} v_h$ = the number of tracts in the state.

Then F is distributed as an F-statistic with degrees of freedom equal to (q, V. -8-q+1)

Reject H_0 if F exceeds the tabular value of F.

It should be noted that while variance calculations included both components of the variance, covariance calculations were only done within DES strata.