An Evaluation of Remote Sensing Data for Estimating Livestock Inventories

by

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INTRODUCTION AND SUMMARY

Previous Research

During the middle 1960's, the Statistical Reporting Service sponsored research in an effort to explore, apply and develop remote sensing techniques for the purpose of estimating livestock inventories. The School of Forestry of the University of California (UC) at Berkeley conducted the research, the results of which indicated the feasibility of aerial photographic inventories of livestock. Moreover, the research indicated the scale, time of day, season of year and overlap of stereographic coverage that collectively would yield an optimum result. 1/

The force of these findings and other considerations led, in April 1967, to a large scale aerial-photo survey which took place in the Sacramento Valley of California. 2/ For that survey there were two sampling strata: a range stratum and a cultivated stratum. Each stratum was subdivided into four domains according to ground cover. Photo counts and ground counts of livestock were thus compared according to stratum and domain. The agreement between ground and photo counts found in the cultivated stratum was termed encouraging. However, sources of error that arose in the counts for the cultivated stratum carried over with greater frequency and magnitude to counts for the range stratum. Most errors resulted from land cover and shelters, and animal clusters.

The former prevented the detection of livestock; the latter made it difficult to distinguish or count individual livestock within groups. Sources of error attributable to the range stratum alone were background clutter which could not be distinguished from livestock and free boundaries permitting livestock to roam in and out of segments.

On the positive side, the report concluded:

1. Access to remote areas is easily accomplished.
2. Large areas of land are covered quickly.
3. Objectivity in livestock counting can be attained.
4. It is possible to reduce bias from imperfect communication between enumerator and respondent.

1/ For results of original survey see: "The Inventory of Crops and Livestock by Means of Aerial Photography," by R. N. Colwell, D. T. Lauer and W. C. Draeger, June 30, 1965.

2/ For a detailed discussion of past remote sensing research of livestock inventories see: "Use of Remote Sensing for Livestock Inventories," by H. F. Huddleston and E. H. Roberts, Fifth Annual Symposium on Remote Sensing, 1970.

The final and significant conclusion was that before becoming an integral part of a data collection system, remote sensing should be undertaken on an operational scale survey.

Survey Objectives

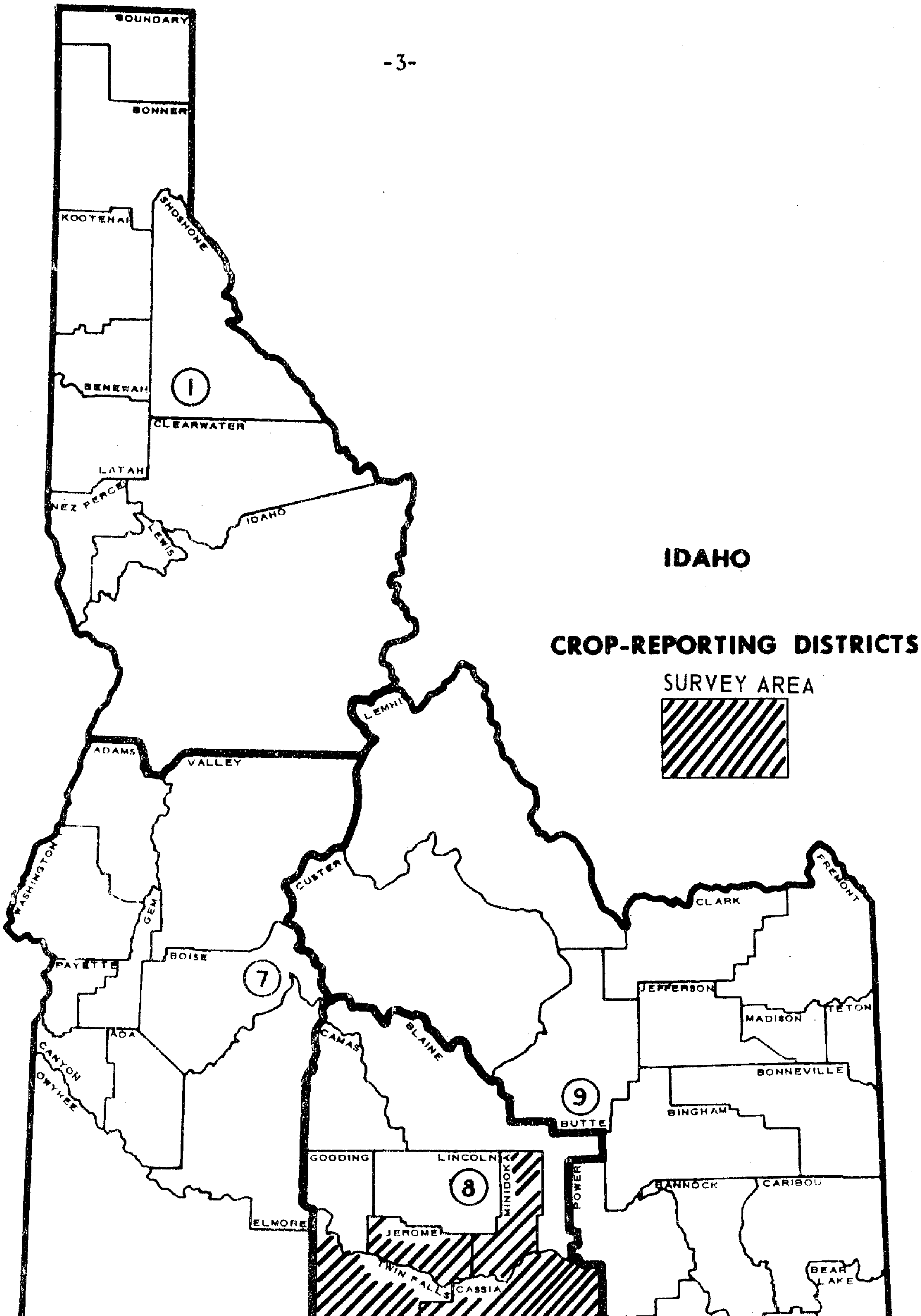
This project, which took place in the Idaho counties of Jerome, Cassia, Twin Falls, and Minidoka 1/ during May and June of 1969, was a logical extention of the 1967 work. The primary objectives were the simulation of an operational aerial photo survey for estimating livestock inventory and its concomitant features. Other objectives included the analyzing of differences in data provided by color and black-white photography; investigation of methods of photo interpretation; determining the suitability of aerial photography as a quality control technique for a major livestock survey; employing an observer in the aircraft to locate compact groups of animals and spotting location of animals within sampling units on maps or photos; and exploration of aerial photography as the cheap data source in a double sampling estimator.

Ratio of Photo Counts to Ground Enumeration

The following table provides an overall comparison between the 1967 Sacramento Valley study and the 1969 Idaho survey of the ratio of photo counts to ground enumeration for numbers of cattle and sheep by stratum.

Stratum	Cattle		Sheep	
	1967	1969	1967	1969
	(percent)	(percent)	(percent)	(percent)
Cultivated	85	40	131	31
Range	63	54	93	90

1/ See figure 1, page 3 for the geographic location of the test site area.


IDAHO
CROP-REPORTING DISTRICTS
SURVEY AREA
1
7
8
9
BOUNDARY
BONNER
KOOTENAI
SHOSHONE
BENEWAH
CLEARWATER
LATAH
NEZ PERCE
LEWIS
IDAHO
LEMHI
ADAMS
VALLEY
WASHINGTON
GEM
PAYETTE
BOISE
CUSTER
CLARK
FREMONT
JEFFERSON
MADISON
TETON
ADA
CANYON
OWYHEE
CAMAS
BLAINE
BUTTE
BONNEVILLE
BINGHAM
GOODING
LINCOLN
MINIDOKA
POWER
BANNOCK
CARIBOU
JEROME
ELMORE
TWIN FALLS
CASSIA
BEAR LAKE
ONEIDA
FRANKLIN

USDA

The ratio of photo counts to ground enumeration is considerably less for the 1969 study - particularly in the cultivated stratum. Several factors are believed to have been responsible for this decline in accuracy of livestock counts. 1) For black and white photography, a scale of 1:5000 was used in the 1967 work; in this project a scale of 1:6000 was used which is slightly smaller than optimum scale. For color photography, the scales for Sacramento Valley and Idaho were 1:2140 and 1:3000, respectively. Previous research has shown that a scale as small as 1:8000 is often satisfactory for making livestock inventories, but that a scale of no smaller than 1:5000 is necessary to obtain highly accurate results consistently. 2) The photo-interpretation was begun as soon as the photos became available and was to be completed as soon as possible to provide a simulation of an operational survey. During the 1967 work no time constraints were placed on the interpreters. 3) The unfavorable circumstance under which the observer in the aircraft was permitted to function completely nullified his effectiveness in locating animals and directing overhead photos of the compact clusters of animals. The combined effects of a less favorable scale, more stringent time constraints during interpretation and nullifying the role of the aircraft observer are believed to have been largely responsible for the decline in accuracy of photo-interpretation results in this survey.

The ratio of estimated totals of photo counts to re-enumeration for this survey are listed below for each species-class by stratum.

Stratum	Cattle		Sheep		Swine		Horses	
	Total	Young	Total	Young	Total	Young	Total	Young
	(percent)		(percent)		(percent)		(percent)	
Cultivated	40	38	31	7	8	0	61	164
Range	54	28	90	---	---	---	---	---

Fewer livestock were counted on the photos than were reported by any of the ground surveys for each species-class with the exception of colts in the cultivated stratum. Apparently misinterpretation resulted in mis-classifying some cattle as horses, causing the higher percentage for horses. Also, a larger percentage was obtained for total animals than for young animals.

Interpreter Variation

From a limited amount of data the following deductions concerning individual counter consistency were made: 1) interpreter one tended to count more horses than other interpreters, 2) interpreter two tended to count fewer cattle, and 3) interpreter two was inconsistent, classifying some animals as cattle the first time and sheep the second time. However, multivariate tests indicate the differences between counters were not significant for total and young cattle and total sheep in the cultivated stratum or total and young cattle in the range stratum on black and white prints.

Black and White vs Color Photography

Generally speaking, more livestock (by species) were counted on color photographs than on black and white photographs. However, multivariate tests indicate the difference is not statistically significant for total and young cattle over the cultivated or range stratum.

Double Sampling Estimation

A very promising use of remote sensing data would be in a double sampling estimate if it were a cheaper source of data. In double sampling a large sample is used for the cheaper data and a subsample of the large sample is selected for the more costly data. Information from the larger sample can be used in the sample selection, or in difference, ratio or regression estimation. The use of remote sensing data as a cheaper data source in a double sampling estimate would be contingent upon the data being utilized for multiple purposes such as crop identification, soil mapping, or other agricultural and non-agricultural uses. Methods need to be developed for multiple uses of remote sensing data so it may be utilized as the cheaper data source in double sampling estimation.

Quality Control

Another possible use of remote sensing data would be as a quality control technique for ground data livestock surveys. As such, the remote sensing data would not be used directly in the estimation of livestock inventories, but would provide a check on the ground data. Furthermore, the use of this technique might allow for the detection of recurring ground data errors, enabling corrective action to be taken for subsequent surveys. The data provided by remote sensing yields a more objective and independent (but not necessarily more precise or accurate) check on enumerative interview surveys than that provided by a follow-up interview for quality control.

The objectivity arises since remote sensing data is not subject to the same communication, response, data recording and processing errors that the enumerative interview data is subject to.

Photo counts from aerial photography would be most useful in providing an indication of the minimum number of livestock in a field, tract, or segment. The supplemental notes to Tables 4 and 5, pages 34 and 41, illustrate some of the quality control potential of remote sensing data. A photo count of less than one-half the enumerative interview number or greater than the enumerative interview number would often indicate an error in the ground data for cattle and sheep (both total and young). Remote sensing might be a useful technique for determining livestock presence in a field, since, if more than ten head of cattle, sheep, or horses were present some positive photo counts were recorded. The possible uses of remote sensing data are dependent upon a strong relationship between remote sensing data and data collected by existing ground surveys. For remote sensing data to be used in estimating livestock inventories, it must ultimately be related to the actual livestock present in each sampling unit. Efforts to develop and test promising methods of improving the accuracy and rapidity of photo interpretation could increase the operational feasibility of photo livestock surveys. Specifications of the photographic system for various types of livestock surveys need to be investigated. Coverage of range areas requires a very large volume of photography. Methods of combining a base sample of photography with a sample selected by unequal probabilities designated by an observer in the photography aircraft should be developed and tested.

Non-sampling Errors

Inconsistent answers from respondents were identified as a major source of non-sampling errors. Response errors in the June Enumerative Survey and Re-enumeration Survey appear to have been a serious problem in the evaluation of the potential of remote sensing in this pilot survey. The June Enumerative Survey missed many young cattle according to the results of both Re-enumeration Survey and the photo counts. Problems were also encountered because of inaccurate reporting of movement on the June Enumerative Survey. These errors were attributed to the respondents though it is possible that these could have been due to enumerator variations or the result of enumerators asking for information which was not known accurately by the respondent.

I. PROCEDURES

The procedures section is divided into two parts; survey procedures and computation procedures.

A. Survey Procedures

This survey was conducted in accordance with the procedures outlined in the June Enumerative Survey (JES) interviewer's manual. Supplemental questions on the nature of ground cover and number and kind of livestock species were attached to the Idaho JES questionnaire. Examples of these materials and the editing instructions for the supplemental questions are shown in Appendix II, Exhibits A-C, pages 84-97.

The frame contained two strata: the range stratum and the cultivated stratum. The cultivated stratum was further divided into five domains as follows:

Domain	Description of Domain
A	Man-made cover in a relatively small field.
B	Man-made cover in a small part of a larger field.
C	More than five percent natural cover within the field (not classified A or B).
D	Trees or brush in the field boundary, but five percent or less cover (not classified A or B).
E	Five percent or less cover and no border cover (not classified A or B).

Ground data collection began in late May with the enumeration of the JES segments. Following the JES, a subsample of 38 segments was selected for aerial photography and re-enumeration. Segment selection was with unequal probability in order to obtain data for livestock and field cover not common in the survey area. Instructions for listing segments by classes and selecting the sample segments for photography are shown in Appendix II, Exhibit D, page 99.

Specifications for the aerial photography included simultaneous black and white stereographic coverage and a subsample of color coverage; the former at a scale of 1:6000, the latter at 1:3000. 3/ Each flight had an aerial

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3/ See Appendix I, page 81.

observer to locate concentrations of livestock for separate photography. However, the aircrafts limited space did not allow the observer to function as planned. He rode backwards, could only see out one side of the plane and not directly below it. The observer's role, near the end of the photography phase, was reduced to determining whether photography could be taken under less than desirable weather conditions.

The aerial photography was obtained about two weeks after the JES and necessitated a re-enumeration corresponding to the date of flight. An attempt was made to measure changes in livestock numbers for the tracts between the dates of the JES and the aerial photo survey (APS). Moreover, when differences in tract totals for the JES and re-enumeration survey (RES) could not be explained by livestock movement, follow-up visits were made. Even then, difficulties were encountered in obtaining accurate livestock movement information. 4/

Using the acquired photography, the School of Forestry at UC delineated the segment and count-cell boundaries on black and white prints and color photo strips. The center cell was drawn on all black and white exposures of a segment to prevent underlap and overlap. They then performed the initial photo interpretation. For each exposure, the livestock counts by species were recorded and later summarized and expanded to segment totals. Photo interpretation of color strips was independent of that for black and white prints.

Upon completion of photo interpretation at UC, all prints were sent to Standards and Research Division (S&RD) of the Statistical Reporting Service (SRS). Field boundaries, corresponding to those enumerated during the June Enumerative Survey were added to each exposure identified as containing livestock. Further interpretation, following UC procedures, provided remote sensing data by domains. 5/

The following is a list of major activities for the 1969 Idaho Aerial Photo Livestock Survey:

4/ Re-enumeration instructions and questionnaires are shown in Appendix II, Exhibits E and F, pages 103-106.

5/ Photo interpretation instructions and forms are shown in Appendix II, Exhibit G, page 114.

1. May 20-22: State JES Training School for enumerators.
2. May 23: Additional training for enumerators taking part in the aerial photo livestock survey.
3. May 26 - June 6: Field enumeration for the JES.
4. June 7: Selection of sample segments for photo coverage and ground observations.
5. June 8: Supplemental instructions given to members of ground crew.
6. June 9-17: Weather and other conditions permitted five days for aerial photography.
7. June 13-20 RES in previously selected segments.
8. June 30 - August 1: Photo interpretation by School of Forestry at the University of California.

The basic data came from four sources:

1. JES (unadjusted data): the results of the initial survey.
2. JES (adjusted data): the results of the initial survey interviews adjusted by adding or subtracting changes in livestock movement occurring between the date of aerial photography and the JES. This was an attempt to update the original survey data to the date of the flight.
3. RES data: the results of a second interview near the time of the photo flight. Questions on livestock numbers corresponded to the date of flight, while livestock movement corresponded to the interim of the initial survey and the flight date.
4. Remote Sensing data: photo interpreter's counts for livestock by species obtained from black and white prints. Segment totals for the above are shown in tables 4 and 5, pages 34-41, along with notes describing data problems and inconsistencies.

B. Computational Procedures

1. Estimates of Totals: The data were expanded by segments before making comparisons since the selection of units was with unequal probability. Subsequently, they were summed to provide inventory estimates of cattle, sheep, swine and horses (total, mature and young) for the cultivated and range strata. The data for fields in each domain of the cultivated stratum were expanded by segments and summed to estimate inventories.

The expanded data by domain may be expressed as $Y_{ijk}=E_j F_j y_{ijk}$, where Y_{ijk} is the expanded number of livestock in the i-th species-class, j-th segment, k-th domain; E_j is the reciprocal of the probability of selecting the segment; F_j is the reciprocal of the probability of selection at the 2nd stage; and y_{ijk} is the observed number of livestock in the i-th species-class, j-th segment, k-th domain. The expansion over all domains for the i-th species-class, j-th segment is $Y_{ij.} = \sum_{k=1}^{5} Y_{ijk}$. The estimated inventory of each species-class by domain was obtained for each data source by summing over all segments in the stratum. This is denoted as $\hat{Y}_{i.k} = \sum_{j=1}^{n} Y_{ijk}$. Finally, $\hat{Y}_{i..} = \sum_{j=1}^{n} Y_{ij.}$ is the estimated inventory of the i-th species-class over all domains. Table 8, page 49, summarizes the observed number of livestock for the cultivated stratum; table 9, page 51 provides a summary for the range stratum.

2. Estimation of Variance: Presented in tables 10-15, pages 53-60 are the variance estimates of the estimated totals from each data source for the range stratum, cultivated stratum, and domains A, B, D and E of the cultivated stratum. Also included in these tables are the estimated standard deviations and coefficients of variation.

In the cultivated and range strata, the estimated variance of the estimated total over all domains is:

$$\hat{V}ar(\hat{Y}_{i..}) = \frac{n\left[\sum_{j=1}^{n} Y_{ij.}^{2} - \frac{(\sum_{j=1}^{n} Y_{ij.})^{2}}{n}\right]}{n-1}$$

where $\hat{Y}_{i..}$ is the estimated total of livestock in the i-th species-class; $Y_{ij.}$ is the expanded number of livestock for the i-th species-class, j-th segment; and n is the number of segments in the sample.

Each estimated total by domain involves two random variables, Y_{ijk} and $M_{.jk} = E_j F_j m_{.jk}$, whereas the estimated total over all domains involves only one random variable $Y_{ij.} = \sum_{k=1}^{n} Y_{ijk}$. In this case, Y_{ijk} is as previously defined. $M_{.jk}$ is the expanded number of fields in the j-th segment k-th domain, and $m_{.jk}$ is the observed number of fields in the j-th segment k-th domain. Since, by domain, each of these random variables contributes to the variance of the estimated totals, the estimated variance of a total for a given domain is:

$$\hat{V}ar(\hat{Y}_{i.k}\hat{M}_{..k}) = \hat{V}ar(\hat{Y}_{i.k}) + \hat{V}ar(\hat{M}_{..k}) - 2\ \hat{C}ov(\hat{Y}_{i.k}\hat{M}_{..k}).\ \underline{6/}$$

The first term on the right of the equality can be written as:

6/ Approximate equality for known variance and covariance relative to estimation of variances and covariances.

$$\hat{V}ar(\hat{Y}_{i.k}) = \frac{n\left[\sum_{j=i}^{n} Y_{ijk}^{2} - \frac{\left(\sum_{j=1}^{n} Y_{ijk}\right)^{2}}{n}\right]}{n-1} ;$$

the second term:

$$\hat{V}ar(\hat{M}_{..k}) = \frac{n\left[\sum_{j=1}^{n} M_{.jk}^{2} - \frac{\left(\sum_{j=1}^{n} M_{.jk}\right)^{2}}{n}\right]}{n-1} ;$$

the third term:

$$\hat{C}ov(\hat{Y}_{i.k}\hat{M}_{..k}) = \frac{n\left[\sum_{j=1}^{n} Y_{ijk}M_{.jk} - \frac{\left(\sum_{j=1}^{n} Y_{ijk}\right)\left(\sum_{j=1}^{n} M_{.jk}\right)}{n}\right]}{n-1} .$$

For certain srecies and classes the scarcity of non-zero reports made some estimates extremely imprecise. Consequently, for these items estimates of variance, standard deviation, and coefficient of variation are not shown.

3. Estimation of Correlation Coefficients: The magnitude of the correlation coefficient indicates the degree of relationship between various data sources. For the cultivated stratum, an estimated correlation coefficient greater than .486 implies with a probability greater than .99 that the true correlation coefficient is greater than zero. This is the one percent level of significance. The five percent level is attained when the estimated correlation coefficient is greater than .383. In the range stratum, the one and five percent significance levels are attained with estimated correlation coefficients greater than .707 and .575, respectively. Correlation matrices are shown in tables 16-23, pages 61-68.

In the following correlation coefficient estimate, X_{ijk} and Y_{ijk} represent the expanded number of livestock in the i-th species-class, j-th segment, and k-th domain for their respective data sources X and Y.

$$\hat{\rho} = \frac{\sum_{j=1}^{n} X_{ijk} Y_{ijk} - \frac{(\sum_{j=1}^{n} X_{ijk})(\sum_{j=1}^{n} Y_{ijk})}{n}}{\left\{\left[\sum_{j=1}^{n} X_{ijk}^2 - \frac{(\sum_{j=1}^{n} X_{ijk})^2}{n}\right]\left[\sum_{j=1}^{n} Y_{ijk}^2 - \frac{(\sum_{j=1}^{n} Y_{ijk})^2}{n}\right]\right\}^{1/2}}$$

For certain species and classes in the range stratum and domains B, C, D and E of the cultivated stratum, the correlation estimates were based on only a few positive values, therefore, these estimates are not shown.

II. RESULTS

A. Estimated Totals from Remote Sensing and Ground Data Sources

In evaluating the feasibility of remote sensing with respect to livestock inventories, the estimated totals provided by remote sensing were compared to those provided by ground data sources. The remote sensing data (RS) was taken from black-white photos; the ground data from the re-enumeration (RES). The RES was used for the comparison since it provided data obtained for the date of photography.

Tables 4 and 5, page 34 & 41 show the observed number of livestock by photo counts and RES. The following list provides the number of segments, from a total of 38, for which the photo count was greater than or equal to that of the re-enumeration.

Livestock Specie		Cultivated Stratum	Range Stratum
Cattle -	Total	1	3
	Young	3	2
Sheep -	Total	2	0
	Young	0	0
Swine -	Total	3	0
	Young	0	0
Horses -	Total	4	3
	Young	4	1

The totals estimated by remote sensing and by ground data can be compared by observing the percent counted 7/, shown in table 1 below. These are based upon the estimates in tables 6 and 7, pages 45-48.

Table 1.--Percent counted: Ratio of estimated totals of photo counts to re-enumeration.

Strata and domain	Cattle		Sheep		Swine		Horses	
	Total	Young	Total	Young	Total	Young	Total	Young
	(Percent)		(Percent)		(Percent)		(Percent)	
Range stratum-all	54	28	90	---	---	---	---	---
Cultivated stratum-all	40	38	31	7	8	0	61	164
Domain - A	38	70	21	6	10	0	29	20
Domain - B	19	4	7	9	0	0	63	---
Domain - C	0	---	0	---	---	---	---	---
Domain - D	43	15	---	---	---	---	---	---
Domain - E	70	45	---	---	---	---	99	474

Observing Table 1, several conclusions can be made. The percent counted was low for each species-class with the exception of colts in the cultivated stratum - all domains and totals horses and colts in domain E. A greater percentage was obtained for total animals than for young animals. In general, photo interpretation found fewer animals than did any of the ground enumeration methods. Misinterpretation resulted in misclassifying some cattle as horses and apparently caused the higher percentage for total horses.

The JES seemed to miss many young cattle. During re-enumeration a special effort was made to obtain accurate calf counts. The photo count total for young cattle exceeded the estimates of JES and tended to support the greater estimates of the re-enumeration survey.

B. Relationship Between Remote Sensing and Ground Data

The study of the relationship between remote sensing and ground data provides one method of determining the practicability of applying remote sensing to livestock inventories. Quite naturally, the correlation coefficient arises in the investigation. In the cultivated stratum, when the estimated correlation coefficient exceeds 0.486, the population correlation coefficient is greater than zero unless a certain event with a probability of 0.01 occurred. An

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7/ Percent counted is equal to the quotient of count by remote sensing (RS) and count by re-enumeration (RES) times 100.

estimated correlation coefficient greater than 0.383 implies the population correlation coefficient is greater than zero unless a certain event with a probability of 0.05 occurred. In the range stratum, the one and five percent significance levels are attained when the estimated correlation coefficients are greater than 0.707 and 0.575, respectively. The one and five percent significance levels are indicated by a double and single asterisk, respectively, in the correlation coefficient matrices, Tables 16-23, pages 61-68.

The relationships among the types of ground data are considered first. In theory, the JES-adjusted for movement (JES-adj.) and the RES should have been identical; that is, the correlation coefficient should have been +1. However, the observed data and estimated totals plainly indicate the two are not identical. If these two types of ground data are not contradictory and measure livestock numbers accurately, then, as random variables, they should at least be highly correlated. In those cases for which enough data was available to estimate the correlation coefficient between JES-adj. and RES with precision, most items were significantly correlated, i.e. the correlation coefficient was estimated to be different than zero. The exceptions were: 1) total cattle and total sheep in the range stratum, and 2) colts in domain A, calves and lambs in domain B, and total horses in domain D of the cultivated stratum. Colts in domain A were significantly correlated at the five percent level. Total cattle in the range stratum and total horses in domain D had nonsignificant positive correlations. Total sheep in the range stratum and lambs in domain B had small negative coefficients; whereas, the calves in domain B had a -0.600 coefficient, which is significatly less than zero at the one percent level.

The difficulty in obtaining accurate livestock movement data partially accounts for the difference between the JES-adj. and the RES data. The movement questions were utilized to obtain the difference between the JES-unadj. and JES-adj. The JES-unadj. and the JES-adj. should be well correlated when there is a constant amount of movement within each segment, or when there is little reported movement; the same would hold true for the correlation between JES-unadj. and RES data. Table 2a on the following page lists the species-classes by stratum-domain which were significantly correlated between JES-unadj. and JES-adj. at the one percent level; Table 2b lists the species-classes which were not significantly correlated between JES-unadj. and JES-adj. Tables 2c and 2d do the same respectively, for the relationships between JES-unadj. and RES data. From Table 2 and Tables 16-23, several observations can be made. 1) Several species-classes which were significantly correlated between JES-unadj. and JES-adj. were not significantly correlated between JES-unadj. and RES. Those species-classes are as follows: in the cultivated stratum - calves in all domains, lambs in domain B, total horses in domain D, and total cattle in domain E; in the range stratum total cattle and total sheep. Since these species-classes were significantly correlated between JES-unadj. and JES-adj., this was interpreted to mean the

Table 2.--Relationships between types of ground data. 1/

Table 2a.--Species-classes significantly correlated between JES-unadj. and JES-adj. $\alpha = 0.01$

	Cultivated				Range
All Domains	Domain A	Domain B	Domain D	Domain E	Stratum
Total cattle	Total cattle	Total cattle	Total cattle	Total cattle	Total cattle
Calves	Calves		Calves	Calves	Calves
Total sheep	Total sheep	Total sheep			Total sheep
Lambs	Lambs	Lambs			
Total hogs	Total hogs	Total hogs			
Young hogs	Young hogs				
Total horses	Total horses	Total horses	Total horses	Total horses	
Colts					

Table 2b.--Species-classes not significantly correlated between JES-unadj. and JES-adj.

					Range
All Domains	Domain A	Domain B	Domain D	Domain E	Stratum
		Calves			
	Colts			Colts	

1/ Domain C and several species-classes were omitted from these tables because there were too few observations to estimate the correlation.

Table 2c.--Species-classes significantly correlated between JES-unadj. and RES

Cultivated Stratum					Range
All Domains	Domain A	Domain B	Domain D	Domain E	Stratum
Total cattle	Total cattle	Total cattle	Total cattle		
	Calves		Calves	Calves	Calves
Total sheep	Total sheep	Total sheep			
Lambs	Lambs				
Total hogs	Total hogs	Total hogs			
Total horses	Total horses	Total horses		Total horses	
Colts					

Table 2d.--Species-classes not significantly correlated between JES-unadj. and RES

Cultivated Stratum					Range
All Domains	Domain A	Domain B	Domain D	Domain E	Stratum
				Total cattle	Total cattle
Calves		Calves			
					Total sheep
		Lambs			
			Total horses		
	Colts			Colts	

reported movement was negligible or else constant within each segment. However, since these species-classes were not significantly correlated between JES-unadj. and RES, we interpreted this to mean a significant amount of movement occurred. The results of these findings are contradictory, indicating either inaccurate reporting of movement or inaccurate responses to the re-enumeration survey. 2) Remote sensing (RS) data as an independent estimate of the livestock inventory can be used as a check to determine whether the inaccuracy was due to the RES or the JES-adj. When one of the above listed species-class is significantly correlated between RS and RES but is not significantly correlated between RS and JES-adj., this could be interpreted to mean an inaccurate reporting of movement. When the opposite occurs and there is a significant correlation between RS and JES-adj. but not between RS and RES, the implication would be inaccurate responses to the RES. Of the previously listed species-classes, the following were significantly correlated at the one percent level between RS and RES, but were not significantly correlated between RS and JES-adj. In the cultivated stratum - calves in all-domains, lambs in domain B, and total horses in domain D and total sheep in the range stratum. These findings lead us to believe there was an inaccurate reporting of movement for these species-classes. No species-classes were found which were significantly correlated between RS and JES-adj. but not significantly correlated between RS and RES. Cattle in domain E were significantly correlated between both RS and RES, and RS and JES-adj. Colts in domain E and total cattle in the range stratum were not significantly correlated for either.

3) RES data provides a comparison with RS data, again via correlation analysis. If the correlation between RES and RS is high, the implication is that remote sensing is a feasible alternative for livestock inventories. However, a low correlation would indicate the opposite.

For total cattle in the cultivated stratum all-domains and domains A, D and E, estimated correlations between RS and RES data were significant at the one percent level. Even though fifty-four percent of the total cattle were counted in the range stratum, a correlation of .187 does not suggest a very promising relationship between ground enumeration and the photo counts. This could be due to proration of the re-enumeration data and partial photography for some range segments. In the range stratum cattle may have been frequently misinterpreted as horses.

The estimated correlation coefficient for young cattle in the range stratum was significant at the one percent level. In the cultivated stratum, singificance for all-domains, and domains A and E was found. The coefficients for domains D and B were derived from less data than those of other domains and were non-significant.

Significantly correlated at the one percent level were RS and RES data for total sheep in domains A and B of the cultivated stratum. Little data was available for the range stratum and the remaining domains.

For lambs in the cultivated stratum all-domains, and domains A and B, the estimated correlation coefficients between RS and RES data were significant at the one percent level. No lambs were reported in the RES data or RS data for either the range stratum or domains C, D and E of the cultivated stratum.

According to both RES and RS data, no swine were present in either the range stratum or domains C and D. The RES data indicated the presence of swine in domain B, however, none were counted on the photos. In domain E, one hog was counted, but none were reported in the RES data. The correlations for total swine were close to, or equal to zero. No young swine were counted on the photos.

Total horses in domains A, D and E of the cultivated stratum had estimated correlation coefficients significant at the one percent level. No horses were reported by RES data in the range stratum, but many were counted on photos. This occurred because cattle were misclassified as horses. The estimated correlation coefficients for domain B were not significant. No horses were present in domain C. For young horses, the estimated correlation coefficients were not significant.

Table 3a summarizes species-classes for which a probable relationship exists between the RS and RES data. Table 3b, summarizes those species-classes for which no relationship is probable. Several species-classes, and domain C were omitted from the table since there was insufficient data to determine if a relationship existed.

Table 3.--Indication of relationships between remote sensing and ground data

a. Relationship indicated

Range	Cultivated Stratum				
All domains	All domains	A	B	D	E
Calves	Total cattle	Total cattle	Total cattle	Total cattle	Total cattle
Total sheep	Calves	Calves	Total sheep	Total horses	Calves
	Total sheep	Total sheep	Lambs		Total horses
	Lambs	Lambs			
	Total horses	Total horses			

b. No relationship indicated

Range	Cultivated Stratum				
All domains	All domains	A	B	D	E
Total cattle	Total swine	Total swine	Calves	Calves	Total swine
Total swine			Total swine	Total swine	
Young swine	Young swine	Young swine	Young swine	Young swine	Young swine
	Colts				Colts

C. Count Comparison Between Black-White Prints and Color Transparencies

Shown in Tables 24 and 25, pages 69 & 70, are the livestock counts of the color transparencies and corresponding counts from the same area on black-white prints. For color, an average count was used since the transparencies were interpreted twice, each time by a different interpreter.

The ratios of counts from color transparencies to counts from black-white prints are shown below:

Livestock Specie-Class		Cultivated stratum	Range Stratum
Cattle -	Total........	1.13	1.13
	Young........	0.26	1.23
Sheep -	Total........	12.34	
	Young........	15.50	
Horses -	Total........	0.71	

The above data indicates substantial differences between the two types of film. However, the differences are not statistically significant, as will be shown in the following statistical tests.

An attempt was made to determine if the mean counts for black-white photos and mean counts for color photos differed significantly in a statistical sense. Tables 26 and 27, pages 71 and 72, represent counts over photography for specified segments and strata. The presence of two strata necessitates two tests. The assumption basic to both populations concerns their underlying distribution. We assume that each measurement vector -- y_{ij}, i = 1, 2, ...13 for the range stratum, and y_{ij}, i = 1,2,3,4, j = 1,2,...27, for the cultivated stratum -- arose from a multivariate normal distribution with mean vector μ_i and covariance matrix Σ_i. Hence, $y_{1j} \sim N(\mu_1,\Sigma_1)$ and $y_{2j} \sim N(\mu_2,\Sigma_2)$. A further assumption involves equality of covariance matrices, and this will be based on statistical evidence. All tests in this section were conducted at the 95% significance level.

The range stratum test for equality of mean count differences was made first. Data for the range stratum indicates all entries for total and young sheep were zero for both black-white and color prints. Therefore, the mean of each population is zero, hence, the difference of means is zero. This implies that the counting of sheep (total and young) can be done as accurately on black-white as on color photography. However, the individual counts for total and young cattle were both zero and non-zero. Thus, the means are non-zero and differ for each sample. Consequently, it is desirable to know whether their differences differ significantly from zero. In order to ascertain the viability of our assumptions, we first tested for equality of covariance matrices under the null hypothesis $H_0: \Sigma_1 = \Sigma_2$ against the alternative $H_1: \Sigma_1 \neq \Sigma_2$, where Σ_1 and Σ_2 denote to covariance matrices for the black-white and color photography, respectively. The test statistic involved, $V = 2.3026\ mM$, approximates a Chi-square distribution with $\frac{p(p+1)}{2}$ degrees of freedom. A few definitions are in order.

(1) $M = (n_1 + n_2 - 2)\log_{10}|S| - (n_1 - 1)\log_{10}|S_1| - (n_2 - 1)\log_{10}|S_2|$

where S_1 and S_2 are covariance estimates of Σ_1 and Σ_2 and $n_1 = n_2 = 13$, the number of responses;

(2) $S = \frac{[(n_1 - 1)\ S_1 + (n_2 - 1)S_2]}{(n_1 + n_2 - 2)}$; and finally

(3) $m = \left[\frac{1}{(n_1 - 1)} + \frac{1}{(n_2 - 1)} - \frac{1}{(n_1 + n_2 - 2)}\right] \left[\frac{2p^2 + 3p - 1}{6(p + 1)}\right]$ with $p = 2$.

For the range data, the calculations yielded

$$|S_1| = \begin{vmatrix} 14{,}271.03 & 2{,}896.70 \\ 2{,}896.70 & 697.44 \end{vmatrix} = 3{,}880{,}238.68,$$

$$|S_2| = \begin{vmatrix} 17{,}185.57 & 4{,}700.88 \\ 4{,}700.88 & 1{,}630.97 \end{vmatrix} = 1{,}562{,}316.27, \text{ and}$$

$$|S| = \begin{vmatrix} 15{,}728.30 & 3{,}798.79 \\ 3{,}798.79 & 1{,}164.21 \end{vmatrix} = 5{,}929{,}657.03$$

A five place logarithm table (base 10) allows approximations:

(1) $\log_{10}|S_1| = 6.19372$

(2) $\log_{10}|S_2| = 6.77302$

(3) $\log_{10}|S| = 6.58885$

After performing the necessary arithmetic operations the value for $M = 2.53$ and $m = 0.91$. Consequently, $V = 5.30 < 7.81 = \chi^2_3$ and, by virtue of this result we conclude no significant difference exists between Σ_1 and Σ_2.

Having concluded the basic assumptions are viable, we proceed to test for mean count differences between black-white versus color photography; that is, we test for equality of mean vectors under the hypothesis.

H_0: $\mu_1 = \mu_2$ where $\mu_1 = (\mu_{11}, \mu_{12})$ and $\mu_2 = (\mu_{21}, \mu_{22})$ against

H_1: $\mu_1 \neq \mu_2$.

Hotelling's T^2 statistic was employed in testing the above hypothesis. For our case, the statistic reads $T^2_{(p, n_1 + n_2 - 2)} = T^2_{(2,24)} = [n_1 n_2 / (n_1 + n_2)]\, D^2 = 6.5\, D^2$ where:

$$D^2 = [d_1\ d_2\ \dots\ d_p] \begin{bmatrix} s_{11} & s_{12} & \dots & s_{1p} \\ s_{12} & s_{22} & \dots & s_{2p} \\ \cdot & & & \\ \cdot & & & \\ s_{1p} & s_{2p} & \dots & s_{pp} \end{bmatrix}^{-1} \begin{bmatrix} d_1 \\ d_2 \\ \cdot \\ \cdot \\ d_p \end{bmatrix} \quad \text{and}$$

$d_k = \bar{y}_{1k} - \bar{y}_{2k}$, $k = 1,2,\dots,p$.

The data from the range stratum yielded the following T^2:

$$T^2_{(2,24)} \doteq (6.5)\ (-7.96,\ 2.12) \begin{pmatrix} 15728.30 & 3798.79 \\ 3798.79 & 1164.21 \end{pmatrix}^{-1} \begin{pmatrix} -7.96 \\ 2.12 \end{pmatrix}$$

$$\doteq (6.5)\ (-7.96,\ 2.12) \begin{pmatrix} 0.00030 & -0.00098 \\ -0.00098 & 0.00405 \end{pmatrix} \begin{pmatrix} -7.96 \\ 2.12 \end{pmatrix}$$

$$\doteq 0.3849 < 7.142 = T^2_{(2,\ 24)}$$

We accept the null hypothesis, and conclude that no significant difference exists between the mean counts on black-white and color photography in the range stratum.

In testing for mean count difference in the cultivated stratum, the basic assumptions are the same as those for the range stratum. Equality of covariance matrices was tested first, using the approximate χ^2 statistic $V = 2.3026\ mM$. In this case $p = 4$, and $n_1 = n_2 = 27$, where: $M = 52 \log_{10} |S| - 26 \log_{10} |S_1| - 26 \log_{10} |S_2|$ and S_1, S_2 are sample covariance matrices for the two treatments; and $m = .96$. The determinants of the cultivated data covariance estimates follows:

(1) $$|S_1| \doteq \begin{vmatrix} 245.72 & 133.00 & -5.20 & -0.32 \\ 133.00 & 130.08 & -1.85 & -0.12 \\ -5.20 & -1.85 & 9.48 & 0.59 \\ -0.32 & -0.12 & 0.59 & 0.04 \end{vmatrix} = 437.91$$

(2) $$|S_2| \doteq \begin{vmatrix} 378.50 & 31.36 & 259.71 & 11.31 \\ 31.36 & 3.87 & 27.86 & 1.25 \\ 259.71 & 27.86 & 755.95 & 51.79 \\ 11.31 & 1.25 & 51.79 & 4.40 \end{vmatrix} = 179395.62 \text{ and}$$

(3) $S = 1/2\ S_1 + 1/2\ S_2$ so that

$$|S| \doteq \begin{vmatrix} 312.11 & 82.18 & 127.26 & 5.50 \\ 82.18 & 66.98 & 13.01 & 0.57 \\ 127.26 & 13.01 & 382.72 & 26.15 \\ 5.50 & 0.57 & 26.15 & 2.22 \end{vmatrix} = 1761826.40$$

Our calculations yielded the following:

$$M \doteq 52(6.25) - 26(2.64) - 26(5.25)$$

$$\doteq 324.79 - 68.64 - 136.50 = 119.65$$

Consequently $V = (2.3026)(.96)(119.65) \doteq 264.49$, which is greater than $18.307 = X_{10}^2$. Thus, we reject the null hypothesis

$$H_0:\ \Sigma_{11} = \Sigma_{12} \quad \text{and assume} \quad \Sigma_{11} \neq \Sigma_{12}$$

Assuming $\Sigma_{11} \neq \Sigma_{12}$, it is necessary to randomly pair the observations.

Table 26, page 71 reflects the fact of randomization when one compares segment numbers for a given sample number. Now the procedure for testing mean count difference is exactly the same procedure used for the same test on the range stratum. The statistic is $T^2_{(4,52)} \doteq 10.80$, where $T^2_{(4,52)} = 13.5\ D^2$. We computed D^2 from this data arriving at:

$$D^2 = \begin{vmatrix} -0.87 & 2.17 & 2.69 & -0.06 \end{vmatrix} \begin{vmatrix} 0.1897 \times 10^{-17} & -0.1977 \times 10^{-16} & -0.3671 \times 10^{-9} & 0.1766 \times 10^{-1} \\ -0.1977 \times 10^{-16} & 0.2345 \times 10^{-15} & 0.4348 \times 10^{-8} & 0.5650 \times 10^{-15} \\ -0.3671 \times 10^{-9} & 0.4348 \times 10^{-8} & 0.5278 \times 10^{-15} & 0.1064 \times 10^{-7} \\ 0.1766 \times 10^{-1} & 0.5650 \times 10^{-15} & 0.1064 \times 10^{-7} & 0.1977 \end{vmatrix} \begin{vmatrix} -0.87 \\ 2.17 \\ 2.69 \\ -0.06 \end{vmatrix}$$

The 4x4 matrix so closely approximates the zero matrix, that for our purposes we shall consider it such. Thus, since $T^2_{(4,52)} = 10.80 > 0 \doteq 13.5\ D^2$, we accept the null hypothesis that no significant difference exists between mean counts for the black-white and color photography over the cultivated stratum.

IV. Two-and-One Interpreter Count Comparison

A random sample of nearly one-third the black-white prints was selected for reinterpretation. They were then randomly assigned to the three interpreters making photo counts. This exercise in reinterpretation provides an indication of the counting consistency between interpreters and of the counting consistency of the individual interpreter.

In the cultivated stratum, 22, 21, and 19 photos were reinterpreted by interpreters number 1, 2 and 3, respectively. For the range strata, counter 1 reinterpreted 59 prints; counter 2, 54; and counter 3, 59. The photos to be reinterpreted were interspersed with the regular photos during the counting operation and were not identified as such to the counter. Photos that were reinterpreted by the person assigned the regular count were presented at separate points in time. The comparisons between interpreters are shown in Tables 25 through 30, pages 70-75 . Comparisons of interpreters' counts at different times are presented in Tables 31 through 33, pages 76-80 . The data, although limited, seem to indicate that interpreter 1 had a tendency to count more horses and counter 2 tended to find fewer cattle than the other interpreters. Counter 2 was inconsistent; classifying some animals as cattle for the first interpretation and sheep for the second interpretation.

A statistical test was run to determine whether counters C_i, i = 1, 2, 3 were counting consistently on black and white prints the number of cattle (total and young) and sheep (total) in the cultivated stratum, and cattle (total and young) in the range stratum. For this a multivariate analysis of variance (MANOVA) test for mean differences was used. The test involved randomly assigning one of three counters to a randomly chosen photo for re-interpretation. Thus, when C_2 checked on C_1, we entered under $C_1 - C_2$ the difference in counts for that photo. We assumed order of counting inconsequential; that is, if C_2 checked on C_1, the entry would be the difference $C_1 - C_2$, and if C_1 checked on C_2 the entry would be $-(C_2 - C_1) = C_1 - C_2$ (see tables 34, 35, pages 79-80). The test required two further assumptions. The first was that observation vectors are normally distributed. The second concerns equality of covariance matrices, and this assumption was based upon statistical evidence.

We begin by testing in the cultivated stratum. This test concerns consistency between counters and these treatments read $C_i - C_j$, i = 1, 2, 3 j = 2, 3, 1 in that order. All tests were conducted at the 95 percent significant level.

Let Σ_1, Σ_2, and Σ_3 represent the covariance matrices for the populations $C_1 - C_2$, $C_2 - C_3$, and $C_3 - C_1$ respectively. We test then the hypothesis H_0: $\Sigma_1 = \Sigma_2 = \Sigma_3$.

The test statistic is:

$$V = 2.3026 \left\{ 1 - \left[\frac{2p^2 + 3p - 1}{6(p+1)(m-1)} \right] \left[\sum_{i=1}^{m} \frac{1}{n_i - 1} - \frac{1}{\sum_{i=1}^{m} (n_i - 1)} \right] \right\}$$

$$\left\{ \left[\sum_{i=1}^{m} (n_i - 1) \right] \times \log_{10} |S| - \sum_{i=1}^{m} (n_i - 1) \times \log_{10} |S_i| \right\}$$

In the above statistic

$n_1 = 17$, $n_2 = 13$, $n_3 = 10$, $p = 3$, $m = 3$;

$$|S_1| = \begin{vmatrix} 86.27 & 28.86 & 0.96 \\ 28.86 & 15.37 & 2.45 \\ 0.96 & 2.45 & 49.47 \end{vmatrix} = 23972.73$$

$$|S_2| = \begin{vmatrix} 6.19 & 0.29 & -0.51 \\ 0.29 & 16.14 & -0.48 \\ -0.51 & -0.48 & 1.92 \end{vmatrix} = 186.18$$

$$|S_3| = \begin{vmatrix} 6.68 & 5.54 & 3.24 \\ 5.54 & 8.01 & 2.98 \\ 3.24 & 2.98 & 1.60 \end{vmatrix} = 0.08$$

$$|S| = \begin{vmatrix} 40.94 & 13.92 & 1.04 \\ 13.92 & 13.83 & 1.63 \\ 1.04 & 1.63 & 22.41 \end{vmatrix} = 8263.907$$

where $S = \dfrac{\sum_{i=1}^{m} (n_i - 1) S_i}{\sum_{i=1}^{m} (n_i - 1)}$, and S_1, S_2, and S_3 are sample covariance matrices.

We reject the hypothesis if the test statistic V exceeds the upper fractile of the appropriate χ^2 -distribution having $\frac{(m - 1)\, p(p + 1)}{2}$ degrees of freedom. For this case, there were 12 degrees of freedom.

A five-place $\log_{10}$ table gives the following:

(1) $\log_{10} |S_1| = 4.38$

(2) $\log_{10} |S_2| = 2.27$

(3) $\log_{10} |S_3| = 1.10$

(4) $\log_{10} |S| = 3.92$

Calculations yielded V = 2.3026 (0.88)(73.60) = 148.30. Since 148.30 > $\chi^2_{0.05,12}$ = 21.03 we reject H_0 and assume inequality of covariance matrices.

Assuming inequality of covariance matrices, the problem is the so-called Behrens-Fisher problem. For a detailed account of the testing procedure for this case see "An Introduction to Multivariate Analysis" by T. W. Anderson pages 118-122. Another reference would be "The Application of Multivariate Analysis of Variance Methods" by David U. Himmelberger published by the Remote Sensing Group, Research and Development Branch, Statistical Reporting Service, in September 1971.

A computer program designed for the Behrens-Fisher problem simplified the calculations. The condition that $n_1 < n_2 < n_3$ must be satisfied for the Behrens-Fisher problem. Thus, a reordering of treatments was necessary. Let μ_i, i = 1, 2, 3 represent the means of the populations $C_i - C_j$, i = 3, 2, 1, j = 1, 3, 2 in that order. Now, $n_1' = 10$, $n_2' = 13$ and $n_3' = 17$. Rather than test the null hypothesis H_0: $\mu_1 = \mu_2 = \mu_3$ the two degrees of freedom due to treatments were partitioned into single degrees of freedom orthogonal contrasts: H_1: $C_1 \mu_1 - C_2 \mu_2 - C_3 \mu_3 = 0$ and H_2: $C_2' \mu_2 - C_3' \mu_3 = 0$.

The contrast coefficients C_i, i = 1, 2, 3 for H_1 are as follows: $C_1 = n_1'K_1$, $C_2 = n_2'K_2$ and $C_3 = n_3'K_3$ where $K_1 = 3$, $K_2 = 1$ and $K_3 = 1$.

The resulting T^2 is 3.921 with 3 variates and 9 degrees of freedom. The tabular value for $T^2_{[0.05\ (3,9)]} = 16.766$, therefore, we accept H_1.

The contrast coefficients for H_2 are $C_2' = n_2'K_2'$ and $C_3' = n_3'K_3'$ with $K_2' = 17$ and $K_3' = 13$. $T^2 = 6.657$ which is less than 13.350 ($T^2_{[0.05\ (3,120]}$).

Hence, we accept H_2 and in so doing, conclude the group mean vectors are equal.

The test for the range stratum differs from the test on the cultivated stratum only in input data. Since counts for sheep (both total and young) were zero for all prints in the range stratum, the test in the range stratum dealt only with total and young cattle. Again, it was desirable to test for equality of covariance matrices to determine whether the basic assumptions were viable. The test hypothesis is H_0: $\Sigma_1 = \Sigma_2 = \Sigma_3$ against the alternative H_a: $\Sigma_1 \neq \Sigma_2 \neq \Sigma_3$. S_1, S_2 and S_3 are the sample covariance matrices for the respective sample populations $C_1 - C_2$, $C_2 - C_3$, and $C_3 - C_1$. The statistic V is as previously defined. However, in this case $n_1 = 31$, $n_2 = 35$, $n_3 = 42$, $p = 2$, $m = 3$. The determinants of S_1, S_2, S_3 and S follow on next page.

(1) $|S_1| = \begin{vmatrix} 6.28 & 2.17 \\ 2.17 & 1.18 \end{vmatrix} = 2.70$ (2) $|S_2| = \begin{vmatrix} 13.89 & 2.36 \\ 2.36 & 1.16 \end{vmatrix} = 10.54$

(3) $|S_3| = \begin{vmatrix} 1.81 & 0.59 \\ 0.59 & 0.22 \end{vmatrix} = 0.05$ (4) $|S| = \begin{vmatrix} 6.98 & 1.62 \\ 1.62 & 0.8 \end{vmatrix} = 2.96$

Calculations for V yielded V = 2.3026 (.97)(56.25) = 125.66. Since $125.66 > 12.59 = \chi^2_{0.05,6}$ we reject H_0, and assume unequal covariance matrices.

Again the Behrens-Fisher problem arose in the test of the null hypothesis H_0: $\mu_1 = \mu_2 = \mu_3$. However, the two degrees of freedom due to treatments were partitioned into two othogonal contrasts: H_1: $C_1\mu_1 - C_2\mu_2 - C_3\mu_3 = 0$ and H_2: $C_2'\mu_2 - C_3'\mu_3 = 0$.

The contrast coefficients for H_1 are $C_1 = n_1K_1$, $C_2 = n_2K_2$ and $C_3 = n_3K_3$ where $K_1 = 77$, $K_2 = 31$, and $K_3 = 31$. The resultant $T^2 = 5.425$ which is less than $T^2_{[0.05(2,30)]} = 6.885$. Hence, we accept H_1.

The contrast coefficients for H_2 are $C_2' = n_2K_2'$ and $C_3' = n_3K_3'$ with $K_2' = 42$ and $K_3' = 35$. Calculations for T^2 under H_2 yield 0.198 which is less than $T^2_{[0.05(2,33)]} = 6.772$. Hence, we accept H_2 and in so doing conclude the group mean vectors are equal.

The conclusions of these tests indicate there was consistency between counters for total and young cattle and total sheep in the cultivated stratum, and for total and young cattle in the range stratum.

EXAMPLE OF A DOUBLE SAMPLING ESTIMATE

Another use of remote sensing data is in a double sampling estimator as the cheaper 8/ source of data. In double sampling a large sample is used for the cheaper (lower cost per sampling unit) data and a subsample of the large sample is selected for the more costly (higher cost per sampling unit) data. Information from the larger sample can be used in the sample selection (stratification, systematic or probability proportional to size) or in difference, ratio or regression estimation. In the following discussion double sampling, with regression estimation and simple random sampling is considered.

Double sampling with regression estimation can be discussed with greater simplicity for simple random sampling rather than the unequal probability sampling used in this survey 9/. In double sampling, to estimate the total number of a particular species-class of livestock in a specific domain or for all domains, a simple random sample of size n is selected from the N units in the population and then $n' < n$ units (the units could be segments) are selected by simple random sampling as a subsample of the n units.

If the cost function involved can be approximated by the relationship $C = C_1 n + C_2 n'$, where C = total cost, C_1 = cost per unit (segment) for the cheaper data source and C_2 = cost per unit for the more costly data source; then the optimum subsampling rate from the larger sample is approximately:

$$\frac{n'}{n} = \sqrt{\frac{1-\rho^2}{\rho^2}\frac{C_1}{C_2}}$$, where ρ is the correlation

coefficient. Although cost data are not discussed in this report, the costs of obtaining remote sensing data per sampling unit could be much less than for ground data if the data has multiple uses such as livestock inventory, crop identification, soil mapping, or other agricultural and non-agricultural uses.

8/ In some circumstances remote sensing data could be used as the more costly data source.

9/ In this survey a form of double sampling was used with all the enumerative segments in the four county area in the larger sample.

For estimated totals of the number of a particular species and class in a particular domain or in all domains, let:

$\hat{Y}''$ = the double sampling regression estimate,

$\hat{Y}'$ = the estimate from the sample of size n' from ground data (re-enumeration survey data),

$\hat{X}'$ = the estimate from the sample of size n' from remote sensing data and,

$\hat{X}$ = the estimate from the sample of size n from the remote sensing data.

The estimate of Y, the true population total, can be expressed as:

$\hat{Y}'' = \hat{Y}' + b\ (\hat{X} - \hat{X}')$, where b is the estimated coefficient of regression of y on x (the observed values of ground data on remote sensed data). It is expressed as:

$$b = \frac{\sum_{j=1}^{n'} (X_j - \bar{X}')(Y_j - \bar{Y}')}{\sum_{j=1}^{n'} (X_j - \bar{X}')^2}$$, where $\bar{X}'$ and $\bar{Y}'$ are

estimated means from samples of size n' for ground data and remote sensed data, respectively. As an example, take n' = 27 segments. Then all the estimated totals and the estimated coefficient of regression are available except $\hat{X}$ (the estimated total for remote sensing data for n segments). Thus, for total cattle in the cultivated stratum--all domains, $\hat{Y}'' = 271{,}540 + 2.38\ (\hat{X} - 108{,}153)$. For total sheep in the cultivated stratum--all domains, $\hat{Y}'' = 45.702 + 2.42\ (\hat{X} - 14{,}252)$.

The variance of $\bar{Y}''$, the estimated mean from double sampling with regression estimation, is given approximately by

$$\text{Var}\ (\bar{Y}'') = \frac{\text{Var}\ (Y_j)}{n'} \left[1 - \rho^2 \left(1 - \frac{n'}{n}\right)\right]$$, where Var (Y_j)

is the known population variance and ρ is the known coefficient of correlation between Y_j and X_j. This approximation holds reasonably well when n' is sufficiently large. Whenever n is large relative to n', n'/n is near zero and the variance for a regression estimator approaches the value Var $(\hat{Y}'')$ = $\frac{\text{Var}\ (Y_j)}{n'}\ (1 - \rho^2)$. By substituting the estimated correlation coefficient, $\hat{\rho}$ for ρ, the variance of $\hat{Y}'$ can be approximated as a function of $\frac{\text{Var}\ (Y_j)}{n'}$ = Var $(\hat{Y}')$. The relationship of the variance of estimated totals is of course analogous to the variances of the estimated means. Using the example of total cattle in the cultivated stratum-all domains,

$$\text{Var}\ (\hat{Y}'') = \frac{\text{Var}\ (Y_j)}{n'} \left[1 - \hat{\rho}^2 \left(1 - \frac{n'}{n} \right) \right]$$

$$= \frac{\text{Var}\ (Y_j)}{27} \left[1 - (.830)^2 \left(1 - \frac{27}{n} \right) \right]$$

$$= \frac{\text{Var}\ (Y_j)}{27} \left[1 - .6889 + \frac{(.6889\ )(27)}{n} \right]$$

$$= \frac{\text{Var}\ (Y_j)}{27} \left(.3111 + \frac{18.6003}{n} \right).$$

Thus, when n = 100, the variance of Y'' from double sampling with regression estimation would be about one-half the variance from n = 27 segments for the ground (re-enumeration) data alone This statement is anologous to stating $\hat{\text{Var}}\ (\hat{Y}'') \doteq \frac{\text{Var}\ (Y_j)}{2n'}$. When n = 50, the variance would be reduced by about one-third. For total sheep in all domains of the cultivated stratum,

$$\mathrm{Var}(Y'') = \frac{\mathrm{Var}(Y_j)}{27}\left[1 - (.969)^2\left(1 - \frac{27}{n}\right)\right]$$

$$= \frac{\mathrm{Var}(Y_j)}{27}\left[1 - .9390 + \frac{(.9390)(27)}{n}\right]$$

$$= \frac{\mathrm{Var}(Y_j)}{27}\left(.0610 + \frac{25.3530}{n}\right)$$

So, when n = 100, the variance of the estimated total would be reduced about two-thirds by using double sampling with regression rather than estimation from the re-enumeration survey alone. The additional cost would be that of aerial photography and associated costs for 100 segments. For a sample of n = 50, the variance would be reduced approximately two-fifths. The approximate coefficients of variation for total cattle and total sheep in the cultivated stratum are shown below for varying sample sizes:

Re-enumeration Alone		Double Sampling with Regression Estimation 10/	
(n = 27)		(n' = 27, n = 50)	(n' = 27, n = 100)
Total cattle	32.8%	27.1%	23.1%
Total sheep	62.9%	47.4%	35.3%

10/ The coefficients of variation for double sampling are computed using the estimated totals from the re-enumeration survey because the double sampling with regression estimation was not actually carried out.

Table 4.- Observed number of livestock by cultivated segments

Segment number	Type of data	Cattle Total	Cattle Mature	Cattle Young	Sheep Total	Sheep Mature	Sheep Young	Swine Total	Swine Mature	Swine Young	Horses Total	Horses Mature	Horses Young
1540	JES unadj.	62	58	4	0			0			36	34	2
	JES adj.	63	57	6	0			0			36	32	4
	RES	50	35	15	0			0			21	18	3
	RS	24	24	0	0			0			15	15	0
1541	JES unadj.	7	7	0	0	0	0	73	73	0	4	4	0
	JES adj.	135	135	0	0	0	0	115	65	50	6	6	0
	RES	169	158	11	0	0	0	100	50	50	4	0	4
	RS	66	60	6	2	2	0	1	1	0	0	0	0
1543	JES unadj.	0			0			0			0		
	JES adj.	0			0			0			0		
	RES	0			0			0			0		
	RS	0			0			0			0		
1544	JES unadj.	42	39	3	0			2	2	0	2	2	0
	JES adj.	42	39	3	0			5	5	0	1	1	0
	RES	54	48	6	0			3	3	0	1	1	0
	RS	35	33	2	0			0	0	0	0	0	0
1545	JES unadj.	100	60	40	0			0			1	1	0
	JES adj.	100	60	40	0			0			1	1	0
	RES	131	96	35	0			0			1	1	0
	RS	31	24	7	0			0			12	12	0
1548	JES unadj.	0			0			0			0		
	JES adj.	0			0			0			0		
	RES	0			0			0			0		
	RS	0			0			0			0		

- Continued

Table 4 (Cont'd).- Observed number of livestock by cultivated segments

Segment number	Type of data	Cattle			Sheep			Swine			Horses		
		Total	Mature	Young	Total	Mature	Young	Total	Mature	Young	Total	Mature	Young
1550	JES unadj.	225	206	19	2	2	0	23	23	0	7	7	0
	JES adj.	188	171	17	2	2	0	11	11	0	8	7	1
	RES	275	246	29	2	0	2	15	15	0	7	6	1
	RS	181	164	17	0	0	0	1	1	0	3	3	0
1551	JES unadj.	762	762	0	0			0			1	1	0
	JES adj.	762	762	0	0			0			1	1	0
	RES	762	756	6	0			0			1	1	0
	RS	124	122	2	0			0			1	1	0
1554	JES unadj.	0	0	0	0			0			0	0	0
	JES adj.	10	10	0	0			0			0	0	0
	RES	52	46	6	0			0			2	2	0
	RS 1/	(9) 18	(7) 14	(2) 4	0			0			0	0	0
1556	JES unadj.	0			0			0			0		
	JES adj.	0			0			0			0		
	RES	0			0			0			0		
	RS	0			0			0			0		
1558	JES unadj.	0			0			0			0		
	JES adj.	0			0			0			0		
	RES	0			0			0			0		
	RS	0			0			0			0		
1561	JES unadj.	0	0	0	0			0	0	0	0	0	0
	JES adj.	0	0	0	0			0	0	0	0	0	0
	RES	4	4	0	0			0	0	0	1	1	0
	RS	0	0	0	0			1	1	0	0	0	0

- Continued

1/ Only one-half of the segment was photographed. The numbers in parentheses ( ) are the actual photo counts and the other numbers are their expansion to the segmen[t].

Table 4 (Cont'd).- Observed number of livestock by cultivated segments

Segment number	Type of data	Cattle			Sheep			Swine			Horses		
		Total	Mature	Young	Total	Mature	Young	Total	Mature	Young	Total	Mature	Young
2218	JES unadj.	90	81	9	3	3	0	0	0	0	4	4	0
	JES adj.	90	81	9	0	0	0	0	0	0	2	2	0
	RES	98	89	9	75	45	30	0	0	0	9	8	1
	RS	7	7	0	30	25	5	5	5	0	1	0	1
2219	JES unadj.	156	155	1	7	7	0	2	2	0	5	5	0
	JES adj.	156	155	1	7	7	0	2	2	0	5	5	0
	RES	151	119	32	0	0	0	0	0	0	9	8	1
	RS	63	60	3	2	2	0	0	0	0	1	1	0
2221	JES unadj.	989	942	47	16	11	5	0			7	7	0
	JES adj.	989	942	47	16	11	5	0			7	7	0
	RES	1132	992	140	16	13	3	0			7	7	0
	RS	543	476	67	0	0	0	0			0	0	0
2222	JES unadj.	104	103	1	53	53	0	16	16	0	8	8	0
	JES adj.	104	103	1	53	53	0	16	16	0	8	8	0
	RES	91	79	12	53	30	23	15	2	13	7	7	0
	RS	50	35	15	0	0	0	0	0	0	7	2	5
2223	JES unadj.	369	359	10	0			0	0	0	34	34	0
	JES adj.	395	372	23	0			0	0	0	35	35	0
	RES	416	222	194	0			0	0	0	36	36	0
	RS	202	150	52	0			4	4	0	11	9	2
2225	JES unadj.	164	163	1	856	290	566	12	12	0	7	7	0
	JES adj.	111	109	2	822	290	532	8	8	0	7	7	0
	RES	115	109	6	605	405	200	7	7	0	8	8	0
	RS	58	31	27	246	233	13	0	0	0	4	4	0

- Continued

Table 4 (Cont'd).- Observed number of livestock by cultivated segments

Segment number	Type of data	Cattle			Sheep			Swine			Horses		
		Total	Mature	Young	Total	Mature	Young	Total	Mature	Young	Total	Mature	Young
2227	JES unadj.	55	50	5	0			35	27	8	5	5	0
	JES adj.	55	50	5	0			33	25	8	5	5	0
	RES	56	48	8	0			27	20	7	4	4	0
	RS	37	30	7	0			0	0	0	2	2	0
2230	JES unadj.	216	198	18	0			0			0	0	0
	JES adj.	216	198	18	0			0			0	0	0
	RES	107	91	16	0			0			4	4	0
	RS	32	32	0	0			0			1	1	0
2231	JES unadj.	0			0			0			0		
	JES adj.	0			0			0			0		
	RES	0			0			0			0		
	RS	0			0			0			0		
2232	JES unadj.	0	0	0	0			68	68	0	0	0	0
	JES adj.	5	4	1	0			68	68	0	0	0	0
	RES	5	4	1	0			68	68	0	3	3	0
	RS	0	0	0	0			5	5	0	0	0	0
2376	JES unadj.	46	45	1	0			58	9	49	7	7	0
	JES adj.	70	69	1	0			59	4	55	7	7	0
	RES	69	48	21	0			50	27	23	6	6	0
	RS	52	40	12	0			0	0	0	0	0	0
3394	JES unadj.	0			0			0			0		
	JES adj.	0			0			0			0		
	RES	0			0			0			0		
	RS	0			0			0			0		

-Continued

Table 4 (Cont'd).- Observed number of livestock by cultivated segments

Segment number	Type of data	Cattle			Sheep			Swine			Horses		
		Total	Mature	Young	Total	Mature	Young	Total	Mature	Young	Total	Mature	Young
3397	JES unadj.	0			0			0			0		
	JES adj.	0			0			0			0		
	RES	0			0			0			0		
	RS	0			0			0			0		
3399	JES unadj.	190	190	0	80	80	0	0			0	0	0
	JES adj.	190	190	0	80	80	0	0			0	0	0
	RES	100	100	0	115	115	0	0			4	4	0
	RS	125	110	15	0	0	0	0			28	21	7
3422	JES unadj.	142	112	30	0			0			1	1	0
	JES adj.	144	112	32	0			0			1	1	0
	RES	144	120	24	0			0			0	0	0
	RS	102	94	8	0			0			0	0	0

Notes Relating to Segments Listed in Table 4

Segment	
1541	One tract had 0 cattle, 4 horses, and 73 swine on JES questionnaire, but showed 154 cattle, 8 calves, 4 horses, and 100 swine including 50 young pigs on RES. Most of the cattle (130 head) were in a feedlot not reported in the JES. The change was not explained by the movement questions.
1545	One tract had 21 cattle along a roadway at the time of re-enumeration. The cattle were not reported in the JES and apparently were not in the tract at flight time.
1550	Sixty-six cattle including 19 calves were reported in the JES for one tract but for the JES input were punched as zeros. The data are included in Table 1 as punched (zeros) to reflect all sources of errors in the processed JES. The tract reported 93 cattle including 17 calves in RES.
1551	One tract was a refusal during both the JES and RES. This tract contained a two-acre feedlot in which 750 cattle were estimated. Subsequent aerial photography indicated substantially fewer cattle in the feedlot.
1554	Because segment boundaries were not fenced, 130 cattle could have been in or out of the segment at flight time. None of these cattle were reported in the JES. For the RES, 52 cattle including six calves were prorated by areas in the segment. Because no livestock were reported in the JES, one of the two possible flight lines was selected for photographic coverage. Thus, the RES report is based on a proration and the RS count is based on a two-times expansion.
2218	For one tract no sheep were reported in the JES but 75 were reported in the RES. Followup indicated the sheep were in the tract at the time of June enumeration.
2221	JES reported 56 cattle for one tract. RES indicated seven cattle in the tract but movement questions did not reveal any cattle to have been moved from the segment between the two surveys. These 49 head were later verified by a followup. Incorrect delineation of photographs missed the feedlot containing the seven head. One large feedlot in domain A had more than three-fourths the cattle in this segment.

Segment

2225 One tract had 430 total sheep including 230 lambs in JES, but RES showed only 215 sheep including 30 lambs. Followup revealed that 200 lambs were marketed between the two surveys which were not reported on the RES movement questions. In another tract, 266 total sheep (all lambs) were reported in JES. RES reported 240 total sheep of which only 100 were lambs. JES data should have been correctly enumerated as 260 total sheep including 126 lambs.

2230 The JES reported 66 cattle for one tract and RES only 20 with the difference not reported in the movement questions. A followup found 46 mature cattle had been sold between surveys. Other tracts in this segment had some problems because livestock that could move across segment boundaries were not prorated in JES. For RES, these livestock were prorated by land area.

3399 The operator of one tract could not be contacted for re-enumeration. His wife reported 100 cattle. JES showed 190 cattle and the photo count indicates this was probably the number present at the time of flight. Black and white print photo counts found no sheep, while the color transparency interpretation revealed 127 mature sheep. JES indicated 80 sheep, RES 115.

Table 5.- Observed number of livestock by range segments

Segment number	Type of data	Cattle			Sheep			Swine			Horses		
		Total	Mature	Young	Total	Mature	Young	Total	Mature	Young	Total	Mature	Young
1156	JES unadj.	323	298	25	0			0			0		
	JES adj.	323	298	25	0			0			0		
	RES	393	303	90	0			0			0		
	RS	148	140	8	0			0			0		
1158	JES unadj.	150	90	60	0			0			0		
	JES adj.	150	90	60	0			0			0		
	RES	181	91	90	0			0			0		
	RS 1/	(32)	(22)	(10)									
		96	66	30	0			0			0		
2274	JES unadj.	0			900	500	400	0			0		
	JES adj.	0			900	500	400	0			0		
	RES	0			0	0	0	0			0		
	RS	0			0	0	0	0			0		
2325	JES unadj.	0	0	0	0			0			0		
(fields	JES adj.	51	0	51	0			0			0		
1, 2, 5)	RES	102	51	51	0			0			0		
	RS	0	0	0	0			0			0		
2325	JES unadj.	748	438	310	0			0			0	0	0
(fields	JES adj.	747	437	310	0			0			0	0	0
3, 4, 8)	RES	567	387	180	0			0			0	0	0
	RS	240	200	40	0			0			3	3	0

- Continued

1/ Only one-third of the segment was photographed. The numbers in parentheses ( ) are the actual photo counts and the other numbers are their expansion to the segment level.

Table 5 (Cont'd).- Observed number of livestock by range segments

Segment number	Type of data	Cattle			Sheep			Swine			Horses		
		Total	Mature	Young	Total	Mature	Young	Total	Mature	Young	Total	Mature	Young
2326	JES unadj.	300	160	140	0			0			0		
	JES adj.	300	160	140	0			0			0		
	RES	300	160	140	0			0			0		
	RS	57	42	15	0			0			0		
2327	JES unadj.	0	0	0	0			0			0	0	0
	JES adj.	44	23	21	0			0			0	0	0
	RES	44	23	21	0			0			0	0	0
	RS 2/	(59)	(58)	(1)							(5)	(4)	(1)
		118	116	2	0			0			10	8	2
2330	JES unadj.	315	306	9	45	45	0	1	1	0	6	6	0
	JES adj.	179	153	26	45	45	0	1	1	0	6	6	0
	RES	308	291	17	50	50	0	0	0	0	0	0	0
	RS	265	195	70	45	45	0	0	0	0	1	1	0
2331	JES unadj.	0			0			0			0		
	JES adj.	0			0			0			0		
	RES	0			0			0			0		
	RS	0			0			0			0		
2332	JES unadj.	0	0	0	0			0			0		
	JES adj.	0	0	0	0			0			0		
	RES	0	0	0	0			0			0		
	RS 3/	(4)	(4)										
		72	72	0	0			0			0		

- Continued

2/ Only one-half of the segment was photographed. The numbers in parentheses ( ) are the actual photo count and the other numbers are their expansion to the segment level.

3/ Only one-eighteenth of the segment was photographed. The numbers in parentheses ( ) are the actual photo count and the other numbers are their expansion to the segment level. On later examination of the photography the four mature cattle could not be found.

Table 5 (Cont;d).- Observed number of livestock by range segments

Segment number	Type of data	Cattle			Sheep			Swine			Horses		
		Total	Mature	Young	Total	Mature	Young	Total	Mature	Young	Total	Mature	Young
2333	JES unadj.	260	160	100	0			0			0		
	JES adj.	260	160	100	0			0			0		
	RES	0	0	0	0			0			0		
	RS	35	23	12	0			0			0		
2339	JES unadj.	0	0	0	0			0			0		
	JES adj.	0	0	0	0			0			0		
	RES	250	250	0	0			0			0		
	RS	0	0	0	0			0			0		

Notes Relating to Segments Listed in Table 5

Segment	
1156	The JES should have shown 210 total cattle including 70 calves for one field instead of 140 total cattle and no calves.
1158	This segment was selected for only one-third photo coverage because no livestock were reported on JES by the enumerator. Subsequently 150 cattle were edited into the JES questionnaire. The editing was quite reasonable with respect to the RES, but lack of complete photo coverage limits evaluation of RS data.
2274	Sheep reported in this segment for JES were never in the segment. The entire segment was in domain C.
2327	For RES 260 cattle were prorated by area to 44 head in the segment because the animals were free to cross segment boundaries. Photography was obtained for only one-half the area. This area seems to have included most of the cattle.
2330	The JES showed one tract reported cattle could move across the segment boundary. The RES found all cattle were outside the segment. For another tract, the JES reported movement of 205 cattle from the segment while at the same time showing 205 head inside the tract. The JES also reported 205 head inside the tract.
2332	Since no livestock were reported in the JES this segment was selected for only one-eighteenth photo coverage. Four cattle were counted in this flight line on the aerial photos and expanded to 72 head for the segment. However, in reviewing this photography the four cattle were not located. Because the methods of data collection were to be evaluated, the RS data was not altered.
2333	JES reported 260 cattle in the segment. RES indicated that these cattle were never in the segment. However, RS data indicates some animals were present.
2339	No livestock were reported in the JES or detected on the aerial photography. The RES reported 250 cattle.

Table 6.- Estimated numbers of livestock--cultivated stratum and domain A

Species class		June enumerative (unadjusted) 2/		June enumerative (adjusted for: movement)	Reenumer-ation	Photo counts (black and white)
				Cultivated stratum (total)		
Cattle -	total	(264,897)	257,821	265,457	271,540	108,153
	adult	(247,463)	244,334	250,463	230,013	92,465
	young	(17,434)	13,487	14,994	41,527	15,688
Sheep -	total	(46,760)	49,334	47,495	45,702	14,252
	adult	(20,508)	23,082	22,806	31,401	13,195
	young	(26,252)	26,252	24,689	14,301	1,057
Swine -	total	(13,328)	16,730	18,047	16,121	1,238
	adult	(10,707)	11,857	10,320	10,187	1,238
	young	(2,621)	4,873	7,727	5,934	0
Horses -	total	(6,746)	10,162	10,164	10,268	6,285
	adult	(6,603)	9,978	9,748	9,622	5,228
	young	(143)	184	416	646	1,057
				Domain A 1/		
Cattle -	total		144,740	142,162	152,757	57,299
	adult		140,835	138,603	142,193	49,901
	young		3,905	3,559	10,564	7,398
Sheep -	total		20,002	26,944	27,910	5,885
	adult		4,554	13,059	18,620	5,288
	young		15,448	13,885	9,290	597
Swine -	total		12,725	12,293	11,196	1,151
	adult		7,852	6,868	7,564	1,151
	young		4,873	5,425	3,632	0
Horses -	total		3,111	3,435	3,411	974
	adult		3,111	3,295	2,949	882
	young		0	140	462	92

-Continued

1/ Estimated number of fields: Domain A-4803

2/ Data shown in parenthesis ( ) are expanded numbers for all June enumerative segments in the four county survey area.

Table 6 (Cont'd).- Estimated numbers of livestock--domains B and C

Species class	June enumerative (unadjusted)	June enumerative (adjusted for movement)	Reenumeration	Photo count (black and white)
		Domain B 1/		
Cattle - total	67,190	52,272	54,047	10,1[illegible]5
adult	61,660	55,707	40,656	9,5[illegible]7
young	5,530	-3,435	13,391	5[illegible]8
Sheep - total	5,885	5,609	12,505	9[illegible]9
adult	5,655	5,379	7,494	4[illegible]9
young	230	230	5,011	4[illegible]0
Swine - total	4,005	5,754	4,925	0
adult	4,005	3,452	2,623	0
young	0	2,302	2,302	0
Horses - total	4,241	4,150	2,952	1,8[illegible]2
adult	4,057	3,966	2,952	1,7[illegible]0
young	184	184	0	[illegible]2
		Domain C 1/		
Cattle - total	0	0	2,131	0
adult	0	0	2,131	0
young	0	0	0	0
Sheep - total	3,678	3,678	5,287	0
adult	3,678	3,678	5,287	0
young	0	0	0	0
Swine - total	0	0	0	0
adult	0	0	0	0
young	0	0	0	0
Horses - total	0	0	0	0
adult	0	0	0	0
young	0	0	0	0

1/ Estimated number of fields: Domain B-2017, Domain C-904.

Table 6 (Cont'd). Estimated numbers of livestock--domains D and E

Species class		June enumerative (unadjusted)	June enumerative (adjusted for movement)	Reenumeration	Photo counts (black and white)
			Domain D 1/		
Cattle	- total	9,249	9,249	10,893	4,699
	adult	7,634	7,633	9,926	4,557
	young	1,615	1,616	967	142
Sheep	- total	0	0	0	0
	adult	0	0	0	0
	young	0	0	0	0
Swine	- total	0	0	0	0
	adult	0	0	0	0
	young	0	0	0	0
Horses	- total	508	691	507	92
	adult	508	691	507	92
	young	0	0	0	0
			Domain E 1/		
Cattle	- total	36,642	61,774	51,712	35,980
	adult	34,205	48,520	35,107	28,430
	young	2,437	13,254	16,605	7,550
Sheep	- total	19,769	11,264	0	7,448
	adult	9,195	690	0	7,448
	young	10,574	10,574	0	0
Swine	- total	0	0	0	87
	adult	0	0	0	87
	young	0	0	0	0
Horses	- total	2,302	1,888	3,398	3,357
	adult	2,302	1,796	3,214	2,484
	young	0	92	184	873

1/ Estimated number of fields: Domain D-4455, Domain E-44,527.

Table 7.- Estimated numbers of livestock--range stratum

Species class	June enumerative (unadjusted)		June enumerative (adjusted for movement)	Reenumeration	Photo counts (black and white)
			Range stratum		
Cattle - total	(27,507)	29,614	33,770	49,895	27,048
adult	(17,862)	19,751	20,781	37,030	23,507
young	(9,645)	9,863	12,989	12,865	3,541
Sheep - total	(6,661)	6,661	6,661	522	470
adult	(3,909)	3,909	3,909	522	470
young	(2,752)	2,752	2,752	0	0
Swine - total	(10)	10	10	0	0
adult	(10)	10	10	0	0
young	(0)	0	0	0	0
Horses - total	(63)	63	63	0	1,168
adult	(63)	63	63	0	939
young	(0)	0	0	0	229

1/ Data shown in parentheses ( ) are expanded numbers for all June enumerative segments in the four county survey areas.

Table 8.- Observed numbers of livestock--cultivated stratum and domain A

Species class		June enumerative (unadjusted)	June enumerative (adjusted for: movement)	Reenumer-ation	Photo counts (black and white)
			Cultivated stratum (total)		
Cattle	- total	3,719	3,825	3,981	1,750
	adult	3,530	3,619	3,410	1,506
	young	189	206	571	244
Sheep	- total	1,017	980	866	280
	adult	446	443	608	262
	young	571	537	258	18
Swine	- total	289	317	285	17
	adult	232	204	192	17
	young	57	113	93	0
Horses	- total	129	130	135	86
	adult	127	125	125	71
	young	2	5	10	15
			Domain A 1/		
Cattle	- total	2,115	2,061	2,285	977
	adult	2,044	1,998	2,088	847
	young	71	63	197	130
Sheep	- total	435	586	607	108
	adult	99	284	405	95
	young	336	302	202	13
Swine	- total	202	192	178	16
	adult	145	129	135	16
	young	57	63	43	0
Horses	- total	43	47	49	14
	adult	43	45	41	13
	young	0	2	8	1

1/ Observed number of fields: Domain A-66.

Table 8 (Cont'd).- Observed numbers of livestock--domains B and C

Species class		June enumerative (unadjusted)	June enumerative (adjusted for movement)	Reenumer-ation	Photo counts (black and white)
			Domain B 1/		
Cattle -	total	903	783	808	155
	adult	844	821	650	142
	young	59	-38	158	13
Sheep -	total	72	69	144	10
	adult	67	64	88	5
	young	5	5	56	5
Swine -	total	87	125	107	0
	adult	87	75	57	0
	young	0	50	50	0
Horses -	total	52	52	38	19
	adult	50	50	38	18
	young	2	2	0	1
			Domain C 1/		
Cattle -	total	0	0	21	0
	adult	0	0	21	0
	young	0	0	0	0
Sheep -	total	80	80	115	0
	adult	80	80	115	0
	young	0	0	0	0
Swine -	total	0	0	0	0
	adult	0	0	0	0
	young	0	0	0	0
Horses -	total	0	0	0	0
	adult	0	0	0	0
	young		0	0	0

1/ Observed number of fields: Domain B-28, Domain C-12.

Table 8 (Cont'd).- Observed numbers of livestock--domains D and E

Species class		June enumerative (unadjusted)	June enumerative (adjusted for: movement)	Reenumer- ation	Photo counts (black and white)
			Domain D 1/		
Cattle	- total	133	133	160	82
	adult	113	113	149	79
	young	20	20	11	3
Sheep	- total	0	0	0	0
	adult	0	0	0	0
	young	0	0	0	0
Swine	- total	0	0	0	0
	adult	0	0	0	0
	young	0	0	0	0
Horses	- total	6	10	8	1
	adult	6	10	8	1
	young	0	0	0	0
			Domain E 1/		
Cattle	- total	568	848	707	536
	adult	529	687	502	438
	young	39	161	205	98
Sheep	- total	430	245	0	162
	adult	200	15	0	162
	young	230	230	0	0
Swine	- total	0	0	0	1
	adult	0	0	0	1
	young	0	0	0	0
Horses	- total	28	21	40	52
	adult	28	20	38	39
	young	0	1	2	13

1/ Observed number of fields: Domain D-62, Domain E-666.

Table 9.- Observed numbers of livestock--range stratum

Species class		June enumerative (unadjusted)	June enumerative (adjusted for movement)	Reenumeration	Photo counts (black and white)
			Range stratum		
Cattle	- total	2,096	2,054	2,145	1,031
	adult	1,452	1,321	1,556	854
	young	644	733	589	177
Sheep	- total	945	945	50	45
	adult	545	545	50	45
	young	400	400	0	0
Swine	- total	1	1	0	0
	adult	1	1	0	0
	young	0	0	0	0
Horses	- total	6	6	0	14
	adult	6	6	0	12
	young	0	0	0	2

Table 10.- Coefficients of variation for estimated livestock totals--
cultivated stratum

Type of data	Estimated variance	Standard deviation	Coefficient of variation 1/
		Total cattle	
JES - all	4,669,337,250	68,333	25.8
JES - comp. - unadj.	7,385,317,371	85,938	33.3
JES - comp. - adj.	7,407,099,513	86,065	32.4
RES	7,923,958,326	89,017	32.8
RS	961,411,410	31,007	28.7
		Calves	
JES - all	23,419,800	4,839	27.8
JES - comp. - unadj.	24,424,902	4,942	36.6
JES - comp. - adj.	27,101,385	5,206	34.7
RES	338,260,563	18,392	44.3
RS	31,329,936	5,597	35.7
		Total sheep	
JES - all	1,575,341,685	39,691	84.9
JES - comp. - unadj.	1,554,211,395	39,423	79.9
JES - comp. - adj.	1,435,752,270	37,891	79.8
RES	826,739,838	28,753	62.9
RS	132,939,306	11,530	80.9
		Lambs	
JES - all	6,769,912	2,602	9.9
JES - comp. - unadj.	6,767,294	2,601	9.9
JES - comp. - adj.	5,978,483	2,445	9.9
RES	925,091	962	6.7
RS	5,475	74	7.0
		Total swine	
JES - all	29,535,621	5,435	40.8
JES - comp. - unadj.	47,161,806	6,867	41.0
JES - comp. - adj.	62,419,784	7,901	43.8
RES	48,344,203	6,953	43.1
RS	368,343	607	49.0

1/ Coefficient of variation reported in percent is the standard deviation divided by the mean x 100.

Table 10 (Cont'd).- Coefficients of variation for estimated livestock totals--cultivated stratum

Type of data	Estimated variance	Standard deviation	Coefficient of variation 1/
		Young swine	
JES - all	5,172,625	2,274	86.8
JES - comp. - unadj.	20,307,785	4,506	92.5
JES - comp. - adj.	29,905,898	5,469	70.8
RES	10,384,023	3,222	54.3
RS	0	0	0
		Total horses	
JES - all	5,456,217	2,336	34.6
JES - comp. - unadj.	19,228,400	4,385	43.2
JES - comp. - adj.	19,800,216	4,450	43.8
RES	13,532,975	3,679	35.8
RS	5,308,763	2,304	36.7
		Colts	
JES - all	10,838	104	72.7
JES - comp. - unadj.	33,911	184	100.0
JES - comp. - adj.	136,560	370	88.9
RES	91,649	303	46.9
RS	327,946	573	54.2

1/ Coefficient of variation reported in percent, is the standard deviation divided by the mean x 100.

Table 11.- Coefficients of variation for estimated livestock totals--
domain A, cultivated stratum

Type of data	Estimated variance	Standard deviation	Coefficient of variation 1/
		Total cattle	
JES - comp. - unadj.	6,499,827,406	80,622	55.7
JES - comp. - adj.	6,516,802,268	80,727	56.8
RES	7,004,155,391	83,691	54.8
RS	557,824,024	23,618	41.2
		Calves	
JES - comp. - unadj.	5,834,282	2,415	61.8
JES - comp. - adj.	6,285,020	2,507	70.4
RES	22,603,636	4,754	45.0
RS	10,005,138	3,163	42.8
		Total sheep	
JES - comp. - unadj.	385,605,614	19,637	98.2
JES - comp. - adj.	706,060,449	26,572	98.6
RES	776,719,674	27,870	99.0
RS	19,373,240	4,402	74.8
		Lambs	
JES - comp. - unadj.	240,899,815	15,521	100.5
JES - comp. - adj.	194,919,196	13,961	100.5
RES	86,185,357	9,284	99.9
RS	1,391,369	1,180	197.7
		Total swine	
JES - comp. - unadj.	35,033,117	5,919	46.5
JES - comp. - adj.	35,462,568	5,955	48.4
RES	27,694,869	5,263	47.0
RS	1,134,792	1,065	92.5
		Young swine	
JES - comp. - unadj.	17,036,709	4,128	84.7
JES - comp. - adj.	20,857,423	4,567	84.2
RES	4,054,214	2,014	55.5
RS	984,318	902	----

1/ Coefficient of variation reported in percent, is the standard deviation divided by the mean x 100.

Table 11 (Cont'd).- Coefficients of variation for estimated livestock totals--domain A, cultivated stratum

Type of data	Estimated variance	Standard deviation	Coefficient of variation 1/
		Total horses	
JES - comp. - unadj.	369,948	608	19.5
JES - comp.- adj.	398,718	631	18.4
RES	333,859	578	16.9
RS	697,911	835	85.7
		Colts	
JES - comp. - unadj.	984,318	992	-
JES - comp. - adj.	880,787	939	670.7
RES	911,017	954	206.5
RS	973,973	987	1072.8

1/ Coefficient of variation reported in percent, is the standard deviation divided by the mean x 100.

Table 12.- Coefficients of variation for estimated livestock totals--domain B, cultivated stratum

Type of data	Estimated variance	Standard deviation	Coefficient of variation 1/
		Total cattle	
JES - comp. - unadj.	791,256,013	28,129	41.9
JES - comp. - adj.	210,556,308	14,511	27.8
RES	251,584,101	15,861	29.3
RS	12,943,924	3,598	35.4
		Calves	
JES - comp. - unadj.	15,647,799	3,956	71.5
JES - comp. - adj.	108,181,938	10,401	302.8
RES	50,003,599	7,071	52.8
RS	482,364	695	116.2
		Total sheep	
JES - comp. - unadj.	23,062,180	4,802	81.6
JES - comp. - adj.	23,220,226	4,819	85.9
RES	64,921,847	8,057	64.4
RS	726,378	852	92.7
		Lambs	
JES - comp. - unadj.	331,790	576	250.4
JES - comp. - adj.	331,790	576	250.4
RES	10,241,395	3,200	63.9
RS	284,212	533	115.9
		Total swine	
JES - comp. - unadj.	10,925,216	3,305	82.5
JES - comp. - adj.	27,038,649	5,200	90.4
RES	20,391,597	4,516	91.7
RS	265,205	515	-
		Total horses	
JES - comp. - unadj.	5,684,131	2,384	56.2
JES - comp. - adj.	5,006,025	2,237	53.9
RES	3,723,461	1,930	65.4
RS	1,403,740	1,185	63.6

1/ Coefficient of variation reported in percent, is the standard deviation divided by the mean x 100.

Table 13.- Coefficients of variation for estimated livestock totals--
domain D, cultivated stratum

Type of data	Estimated variance	Standard deviation	Coefficient of variation 1/
		Total cattle	
JES - comp. - unadj.	20,832,448	4,564	49.3
JES - comp. - adj.	20,832,448	4,564	49.3
RES	47,160,305	6,867	63.0
RS	8,662,793	2,943	62.6
		Calves	
JES - comp. - unadj.	1,417,405	1,191	737.0
JES - comp. - adj.	1,417,405	1,191	737.0
RES	994,671	997	103.1
RS	1,190,023	1,091	768.3
		Total horses	
JES - comp. - unadj.	1,258,814	1,122	220.9
JES - comp. - adj.	1,296,107	1,138	164.7
RES	1,065,685	1,032	203.6
RS	1,175,291	1,084	1178.3

1/ Coefficient of variation reported in percent, is the standard deviation divided by the mean x 100.

Table 14.- Coefficients of variation for estimated livestock totals--domain E, cultivated stratum

Type of data	Estimated variance	Standard deviation	Coefficient of variation 1/
		Total cattle	
JES - comp. - unadj.	386,238,633	19,653	53.6
JES - comp. - adj.	710,667,587	26,658	43.2
RES	487,090,324	22,070	42.7
RS	173,112,149	13,157	36.6
		Calves	
JES - comp. - unadj.	55,936,512	7,479	306.9
JES - comp. - adj.	92,571,257	9,621	72.6
RES	83,239,812	9,124	54.9
RS	43,177,523	6,571	87.0
		Total horses	
JES - comp. - unadj.	53,581,271	7,320	318.0
JES - comp. - adj.	53,535,636	7,317	387.6
RES	52,142,225	7,221	212.5
RS	58,928,115	7,676	228.7
		Colts	
JES - comp. - unadj.	63,026,078	7,939	-
JES - comp. - adj.	62,645,989	7,915	8603.3
RES	62,282,856	7,892	4289.1
RS	61,177,440	7,822	896.0

1/ Coefficient of variation reported in percent, is the standard deviation divided by the mean x 100.

Table 15.- Coefficients of variation for estimated livestock totals range stratum

Type of data	Estimated variance	Standard deviation	Coefficient of variation 1/
		Total cattle	
JES - all	65,963,519	8,122	29.5
JES - comp. - unadj.	106,656,140	10,327	34.9
JES - comp. - adj.	102,668,266	10,133	30.0
RES	335,391,270	18,314	36.7
RS	183,424,211	13,543	50.1
		Calves	
JES - all	17,304,983	4,160	43.1
JES - comp. - unadj.	18,847,292	4,341	44.0
JES - comp. - adj.	19,048,558	4,364	33.6
RES	32,566,649	5,707	44.4
RS	3,260,375	1,806	51.0
		Total sheep	
JES - all	38,297,511	6,188	92.9
JES - comp. - unadj.	38,168,467	6,178	92.7
JES - comp. - adj.	38,168,467	6,178	92.7
RES	272,484	522	100.0
RS	220,712	470	100.0

Table 16.- Correlation coefficient matrices--total cattle

Type of data	Photo counts (black and white) (RS)	Reenumeration (RES)	June enumerative (adjusted for movement) (JES - adj.)
		Cultivated stratum	
		All domains	
RES	.830**	---	---
JES - adj.	.792**	.986**	---
JES - unadj.	.784**	.982**	.996**
		Domain A	
RES	.840**	---	---
JES - adj.	.806**	.997**	---
JES - unadj.	.805**	.997**	.999**
		Domain B	
RES	.388*	---	---
JES - adj.	.444*	.988**	---
JES - unadj.	.491**	.764**	.737**
		Domain D	
RES	.858**	---	---
JES - adj.	.847**	.953**	---
JES - unadj.	.847**	.953**	1.000**
		Domain E	
RES	.962**	---	---
JES - adj.	.866**	.887**	---
JES - unadj.	.334	.299	.667**
		Range stratum	
RES	.187	---	---
JES - adj.	.537	.252	---
JES - unadj.	.100	.224	.863**

* Significantly different from zero at the five percent level.
** Significantly different from zero at the one percent level.

Table 17.- Correlation coefficient matrices--young cattle

Type of data	Photo counts (black and white) (RS)	Reenumeration (RES)	June enumerative (adjusted for movement) (JES - adj.)
		Cultivated stratum	
		All domains	
RES	.910**	---	---
JES - adj.	.467*	.561**	---
JES - unadj.	.309	.370	.973**
		Domain A	
RES	.808**	---	---
JES - adj.	.431*	.636**	---
JES - unadj.	.414*	.641**	.976**
		Domain B	
RES	-.007	---	---
JES - adj.	.023	-.600**	---
JES - unadj.	-.060	.439*	.446*
		Domain D	
RES	.013	---	---
JES - adj.	.098	.996**	---
JES - unadj.	.098	.996**	1.000**
		Domain E	
RES	.973**	---	---
JES - adj.	.950**	.989**	---
JES - unadj.	.554**	.666**	.671**
		Range stratum	
RES	.809**	---	---
JES - adj.	.677*	.864**	---
JES - unadj.	.715**	.748**	.848**

* Significantly different from zero at the five percent level.
** Significantly different from zero at the one percent level.

Table 18.- Correlation coefficient matrices--total sheep

Type of data	Photo counts (black and white) (RS)	Reenumeration (RES)	June enumerative (adjusted for movement) (JES - adj.)
		Cultivated stratum	
		All domains	
RES	.969**	---	---
JES - adj.	.956**	.967**	---
JES - unadj.	.959**	.968**	1.000**
		Domain A	
RES	.904**	---	---
JES - adj.	.904**	1.000**	---
JES - unadj.	.903**	1.000**	1.000**
		Domain B	
RES	.807**	---	---
JES - adj.	-.044	.555**	---
JES - unadj.	.012	.601**	.998**
		Range stratum	
RES	1.000**	---	---
JES - adj.	-.015	-.015	---
JES - unadj.	-.015	-.015	1.000**

* Significantly different from zero at the five percent level.
** Significantly different from zero at the one percent level.

Table 19.- Correlation coefficient matrices--young sheep

Type of data	Photo counts (black and white) (RS)	Reenumeration (RES)	June enumerative (adjusted for movement) (JES - adj.)
		Cultivated stratum	
		All domains	
RES	.905**	---	---
JES - adj.	.784**	.935**	---
JES - unadj.	.784**	.935**	1.000**
		Domain A	
RES	1.000**	---	---
JES - adj.	1.000**	1.000**	---
JES - unadj.	1.000**	1.000**	1.000**
		Domain B	
RES	.784**	---	---
JES - adj.	-.038	-.015	---
JES - unadj.	-.038	-.015	1.000**

** Significantly different from zero at the one percent level.

Table 20.- Correlation coefficient matrices--total swine

Type of data	Photo counts (black and white) (RS)	Reenumeration (RES)	June enumerative (adjusted for movement) (JES - adj.)
		Cultivated stratum	
		All domains	
RES	.055	---	---
JES - adj.	.035	.997**	---
JES - unadj.	.039	.974**	.971**
		Domain A	
RES	.084	---	---
JES - adj.	.059	.996**	---
JES - unadj.	.062	.995**	.995**
		Domain B	
RES	.000	---	---
JES - adj.	.000	1.000**	---
JES - unadj.	.000	.995**	.996**

** Significantly different from zero at the one percent level.

Table 21.- Correlation coefficient matrices--young swine

Type of data	Photo counts (black and white) (RS)	Reenumeration (RES)	June enumerative (adjusted for movement) (JES - adj.)
		Cultivated stratum	
		All domains	
RES	.000	---	---
JES - adj.	.000	.849**	---
JES - unadj.	.000	.613**	.907**
		Domain A	
RES	.000	---	---
JES - adj.	.000	.865**	---
JES - unadj.	.000	.866**	1.000**

** Significantly different from zero at the one percent level.

Table 22.- Correlation coefficient matrices--total horses

Type of data	Photo counts (black and white) (RS)	Reenumeration (RES)	June enumerative (adjusted for movement) (JES - adj.)
		Cultivated stratum	
		All domains	
RES	.573**	---	---
JES - adj.	.632**	.935**	---
JES - unadj.	.632**	.937**	.999**
		Domain A	
RES	.544**	---	---
JES - adj.	.398*	.685**	---
JES - unadj.	.314	.653**	.969**
		Domain B	
RES	.279	---	---
JES - adj.	.328	.839**	---
JES - unadj.	.328	.860**	.998**
		Domain D	
RES	.641**	---	---
JES - adj.	-.065	.299	---
JES - unadj.	-.052	.012	.894**
		Domain E	
RES	.648**	---	---
JES - adj.	.505**	.908**	---
JES - unadj.	.493**	.919**	.982**

* Significantly different from zero at the five percent level.
** Significantly different from zero at the one percent level.

Table 23.- Correlation coefficient matrices--young horses

Type of data	Photo counts (black and white) (RS)	Reenumeration (RES)	June enumerative (adjusted for movement) (JES - adj.)
		Cultivated stratum	
		All domains	
RES	-.091	---	---
JES - adj.	-.080	.791**	---
JES - unadj.	-.071	.784**	.992**
		Domain A	
RES	.351	---	---
JES - adj.	-.053	.384*	---
JES - unadj.	.000	.000	.000
		Domain E	
RES	-.061	---	---
JES - adj.	-.061	1.000**	---
JES - unadj.	.000	.000	.000

* Significantly different from zero at the five percent level.
** Significantly different from zero at the one percent level.

Table 24.- Livestock counts for cultivated stratum from color transparencies and black and white prints

Segment number	Average number counted on color transparencies		Number counted on black and white prints	
	Total cattle	Young cattle	Total cattle	Young cattle
1540	3.5	0	3	0
1545	28.5	7.0	23	7
1550	3.0	0	22	2
2218	3.0	0	3	0
2219	14.0	1.0	16	1
2221	57.5	3.0	59	59
2222	32.0	1.5	27	0
2223	48.0	1.5	36	9
3399	68.0	7.0	39	3
Total	257.5	21.0	228	81
	Total sheep	Young sheep	Total sheep	Young sheep
2225	70.5	9.0	16	1
3399	127.0	6.5	0	0
Total	197.5	15.5	16	1
	Total swine	Young swine	Total swine	Young swine
1540	2.0	0	0	0
	Total horses	Young horses	Total horses	Young horses
1545	12.0	0	12	0
3399	0	0	5	0
Total	12.0	0	17	0

Table 25.- Livestock counts for range stratum from color transparencies and black and white prints

Segment number	Average number counted on color transparencies		Number counted on black and white prints	
	Total cattle	Young cattle	Total cattle	Young cattle
1156	116.5	12.5	50	5
1158 1/	426.0	147.0	388	90
2326	8.0	1.0	19	5
2330	255.7	15.0	235	26
2333	0	0	29	11
2335	43.0	1.7	31	7
Total	849.2	177.2	752	144

1/ This segment had special photography which evidently duplicated many areas in the segment. It is shown only as a comparison between comparable color and black and white photography.

Table 26.- Multivariate data--range stratum

Sample number	Segment number	Treatment 1 - B-W photography				Treatment 2 - color photography			
		Cattle		Sheep		Cattle		Sheep	
		Total	Young	Total	Young	Total	Young	Total	Young
1	1156	50	5	0	0	116.5	12.5	0	0
2	1158	380	96	0	0	426	147	0	0
3	2274	0	0	0	0	0	0	0	0
4	2326	19	5	0	0	8	1	0	0
5	2330	235	26	0	0	254	15	0	0
6	2331	0	0	0	0	0	0	0	0
7	2333	29	11	0	0	0	0	0	0
8	2339	0	0	0	0	0	0	0	0
9	2325(1)	0	0	0	0	0	0	0	0
10	2325(2)	0	0	0	0	0	0	0	0
11	2325(3)	12	6	0	0	0	0	0	0
12	2325(4)	19	1	0	0	43	2	0	0
13	2325(5)	0	0	0	0	0	0	0	0

Table 27.- Multivariate data--cultivated stratum

Segment number	Treatment 1 - B-W photography				Sample number	Treatment 2 - color photography				Segment number
	Cattle		Sheep			Cattle		Sheep		
	Total	Young	Total	Young		Total	Young	Total	Young	
1556	0	0	0	0	1	0	0	70.5	9	2225
1545	23	7	0	0	2	0	0	0	0	1558
1540	3	0	0	0	3	32	0	0	0	2222
2225	0	0	16	1	4	57.5	3	0	0	2221
1561	0	0	0	0	5	0	0	0	0	1544
2231	0	0	0	0	6	3	0	0	0	2218
2222	27	0	0	0	7	68	7	127	6.5	3399
2221	59	59	0	0	8	0	0	0	0	1548
1541	0	0	0	0	9	48	1.5	0	0	2223
3394	0	0	0	0	10	3	0	0	0	1550
2230	0	0	0	0	11	0	0	0	0	3394
1558	0	0	0	0	12	0	0	0	0	2232
2227	0	0	0	0	13	0	0	0	0	2230
1544	0	0	0	0	14	0	0	0	0	2376
2232	0	0	0	0	15	0	0	0	0	1541
1543	0	0	0	0	16	0	0	0	0	1561
1548	0	0	0	0	17	14	1	0	0	2219
2218	3	0	0	0	18	0	0	0	0	1543
1551	0	0	0	0	19	0	0	0	0	2227
2376	0	0	0	0	20	0	0	0	0	1551
2219	16	1	0	0	21	0	0	0	0	3397
1554	0	0	0	0	22	0	0	0	0	3422
3397	0	0	0	0	23	285	7.0	0	0	1545
3399	39	3	0	0	24	0	0	0	0	1554
1550	22	2	0	0	25	0	0	0	0	1556
2223	36	9	0	0	26	3.5	0	0	0	1540
3422	0	0	0	0	27	0	0	0	0	2231

Table 28.- Comparison of photo counts--interpreters 1 and 2

Species	Interpreter 1		Interpreter 2	
	Total	Young	Total	Young
	Cultivated stratum 1/			
Cattle	521	35	505	12
Sheep	160	0	191	29
Swine	0	0	0	0
Horses	33	7	2	0
	Range stratum 2/			
Cattle	80	18	60	11
Sheep	0	0	0	0
Swine	0	0	0	0
Horses	0	0	0	0

1/ Includes 17 comparisons (six excluding zeros).
2/ Includes 33 comparisons (four excluding zeros).

Table 29.- Comparison of photo counts--interpreters 1 and 3

Species	Interpreter 1		Interpreter 3	
	Total	Young	Total	Young
	Cultivated stratum 1/			
Cattle	321	72	344	57
Sheep	19	5	0	0
Swine	0	0	4	0
Horses	20	14	2	0
	Range stratum 2/			
Cattle	122	17	137	12
Sheep	45	0	47	0
Swine	0	0	0	0
Horses	1	0	1	0

1/ Includes 13 comparisons (eight excluding zeros).
2/ Includes 37 comparisons (ten excluding zeros).

Table 30.- Comparison of photo counts--interpreters 2 and 3

Species	Interpreter 2		Interpreter 3	
	Total	Young	Total	Young
	Cultivated stratum 1/			
Cattle	19	0	26	13
Sheep	0	0	17	4
Swine	0	0	0	0
Horses	3	0	13	10
	Range stratum 2/			
Cattle	32	1	37	4
Sheep	0	0	0	0
Swine	0	0	0	0
Horses	0	0	0	0

1/ Includes 10 comparisons (two excluding zeros).
2/ Includes 46 comparisons (two excluding zeros).

Table 31.- Comparison of photo counts--interpreter 1 at different times

Species	First interpretation		Second interpretation	
	Total	Young	Total	Young
	Cultivated stratum 1/			
Cattle	31	4	30	9
Sheep	2	0	1	0
Swine	0	0	0	0
Horses	1	0	1	0
	Range stratum 2/			
Cattle	37	9	33	5
Sheep	0	0	0	0
Swine	0	0	0	0
Horses	0	0	0	0

1/ Includes four comparisons (three excluding zeros).
2/ Includes 23 comparisons (five excluding zeros).

Table 32.- Comparison of photo counts--interpreter 2 at different times

Species	First interpretation		Second interpretation	
	Total	Young	Total	Young
	Cultivated stratum 1/			
Cattle	63	0	35	7
Sheep	0	0	23	0
Swine	0	0	0	0
Horses	0	0	0	0
	Range stratum 2/			
Cattle	0	0	0	0
Sheep	0	0	0	0
Swine	0	0	0	0
Horses	0	0	0	0

1/ Includes 9 comparisons (three excluding zeros).
2/ Includes 16 comparisons (zero excluding zeros).

Table 33.- Comparison of photo counts--interpreter 3 at different times

Species	First interpretation		Second interpretation	
	Total	Young	Total	Young
	Cultivated stratum 1/			
Cattle	43	3	43	6
Sheep	0	0	0	0
Swine	0	0	0	0
Horses	1	0	1	0
	Range stratum 2/			
Cattle	28	6	25	0
Sheep	0	0	0	0
Swine	0	0	0	0
Horses	1	0	1	0

1/ Includes 9 comparisons (one excluding zeros)
2/ Includes 17 comparisons (four excluding zeros).

Table 34.- MANOVA data for range stratum

Sample number	$C_1 - C_2$		Sample number	$C_2 - C_3$		Sample number	$C_3 - C_1$	
	Total	Young		Total	Young		Total	Young
1	10	1	1	6	0	1	3	0
2	10	6	2	-4	-1	2	-8	-3
3	2	0	3	-16	0	3	0	0
4	0	0	4	-1	0	.	.	.
.	.	.	5	-1	-1	.	.	.
.	.	.	6	-2	-1	.	.	.
.	.	.	7	12	6	42	0	0
31	0	0	8	1	0			
			9	0	0			
			.	.	.			
			.	.	.			
			.	.	.			
			35	0	0			

Table 35.- MANOVA data for cultivated stratum

Sample number	$C_1 - C_2$				$C_2 - C_3$				$C_3 - C_1$			
	Cattle		Sheep		Cattle		Sheep		Cattle		Sheep	
	Total	Young	Total	Young	Total	Young	Total	Young	Total	Young	Total	Young
1	0	2	0	0	-3	0	6	5	1	-5	0	0
2	16	10	0	0	0	0	13	0	-8	-8	-17	-4
3	0	0	-31	-29	-6	3	0	0	0	0	0	0
4	20	13	0	0	-7	-2	0	0	.	.	.	.
5	-27	-2	0	0	0	12	0	0	.	.	.	.
6	0	0	0	0	-4	5	0	0	.	.	.	.
7	.	.	.	.	-1	-5	0	0				
8	.	.	.	.	-2	2	0	0				
9	.	.	.	.	0	0	0	0				
10					.	.	.	.	0	0	0	0
11					.	.	.	.				
12												
13					0	0	0	0				
14												
15	.	.	.	.								
16	.	.	.	.								
17	0	0	0	0								

APPENDIX I

Specifications for Aerial Photography

1969 Idaho Aerial Photo Livestock Survey

The project for which this photography is to be taken involves the inventory of livestock on a part of the Snake River Plain in southern Idaho. A sampling scheme has been employed whereby the sample areas shown on the accompanying maps were chosen. Not all of the sample areas will be flown. The plan for selection of actual photo sample areas is based on a conventional ground inventory made the week prior to the photography. Flight lines for the complete photographic coverage of all the areas have been drawn on separate maps. Some of the areas will require this complete photographic coverage while others will require that only certain flight lines be flown; some will not be flown at all.

The following specifications describe two-camera system for simultaneously obtaining large format panchromatic photos and smaller format, larger scale color photos. The color camera will be operated only in conjunction with the panchromatic camera, but the panchromatic camera will often be used independently.

This photography will be part of a research effort and will require close preflight and inflight coordination with an on-ground survey team.

1. Cameras - One six-inch focal length camera with a 9" x 9" film format capable of providing a resolution of 40 lines per millimeter. Panchromatic film will be used in this camera.

One twelve-inch focal length frame camera to use 70mm film and provide a 70mm x 9" film format. Color reversal film will be used in this camera to provide transparencies.

2. Camera Mounting - The two cameras must be mounted so that their principal axes remain parallel at all times while allowing normal leveling for aircraft pitch and roll and correction for crab.

3. Camera Operation - Both cameras are to be operated from the same intervalometer in order to achieve simultaneous exposure. The camera using color film will be operating on only one-third to one-half of the flight lines flown.

4. Demonstrated System Capability - The contractor must demonstrate his capability to provide a working system meeting the above specifications before a bid can be accepted.

5. Location - Southern Idaho. Flight lines within approximately 35 of the 58 areas shown on the accompanying maps of Cassia, Gooding, Jerome, Lincoln, Minidoka, Owyhee and Twin Falls counties will be flown. Specific flight lines will be chosen about two days before the photography is to start. Changes may be required during the photographic mission.

6. Date of Photography - Photography to start the morning of June 9, 1969, weather permitting. It is anticipated that three days will be required for photo acquisition.

7. Number of Photographs Anticipated - 800-1000 9" x 9" panchromatic; 400-500 70mm x 9" color transparencies.

8. Film and Filter - Nine 1/2" Plus X Aerographic or equivalent, Wratten 12 filter; 70mm Ektachrome Aero or equivalent, HF-3 filter if necessary.

9. Prints and Photo Labeling - One set of prints will be required. These should be Logetronically printed on single weight glossy paper. All prints and color transparencies shall be numbered and a log kept so that each photograph can be identified as to the area photographed and so that corresponding panchromatic and color photographs can be matched.

10. Flight Altitude - Photography will be taken from an altitude of 3,000 feet above the terrain. A small amount of lower altitude coverage may be necessary in some areas.

11. Overlap - Sixty percent overlap as seen on the panchromatic photos will be obtained for most of the flight lines. Ten percent overlap may be specified for certain of the lines at the time of flight.

12. Time of Day - The nature of the livestock inventory project requires that the photography be obtained during early morning and late evening hours. Midday photography must be avoided. 1/ The hours of 0730-1045 and 1545-1830 local daylight savings time provide solor altitude between 20° and 55° which should be favorable for livestock detection.

13. Observer Aboard Aircraft - The design of the experiment requires that an employee of the Statistical Reporting Service, USDA, be aboard the photographic aircraft in order to make certain real-time decisions.

These concern sampling rates and flight lines selection for photographic coverage based on aerial observations of livestock numbers within the test areas. 2/

1/ Weather conditions forced some midday photography because of the afternoon buildup of cumulus clouds.

2/ The observer was unable to function as planned. Near the end of the photography phase the role of the observer was altered to that of determining if photography could be taken under less than desirable weather conditions.

14. Air-to-Ground Communications - It will be necessary to have radio communication between the photographic aircraft and various ground crews performing simultaneous inventory work in the areas being photographed.

It is anticipated that the Forest Service will provide six field radios for this purpose. Experience has shown that the aircraft will require an outside antenna for satisfactory operation of these units. In the event the Forest Service field units are not available, the contractor will be expected to provide for air-to-ground communication.

APPENDIX II

EXHIBIT A

Supplemental Interviewers Manual

Idaho Aerial Photo Livestock Survey

Twin Falls, Minidoka, Jerome and Cassia Counties

1. Objectives

The main objective is to simulate an operational survey using aerial photography. Emphasis will be on livestock and major crops. Also, the feasibility of aerial photography as a quality control technique for enumerative surveys will be studied. Comparison of estimates derived from enumeration and aerial photography will be made. An attempt at rapid photo interpretation will be made.

Because the aerial photography will be taken at nearly the same time as the June Enumerative Survey, estimates from each method will be comparable.

(a) Independent estimates will be made from each source of data--aerial photos and June Enumerative Survey.

(b) A quality check of the June Enumerative Survey is possible by making adjustments for the movement of livestock between enumeration and flight time.

2. Background

Initial efforts by SRS to explore the feasibility of making livestock inventories by aerial photography started in California in 1963. At that time a wide range of photographic scales were used to determine the capabilities of making livestock identification and counts. Also, simulated operational flights were made over portions of Utah, Colorado and Wyoming. Conclusion: It appeared feasible to detect, identify and count livestock at scales of 1/8000 to 1/7000.

During 1964 and 1965, the University of California at Berkeley entered a contract with USDA for a study of scales, film-filter combinations, and conditions in various parts of California. They were to develop livestock interpretation keys; a representative display of livestock types, breeds, ages, sexes was located at the base of a water tower in Davis and photographed at various sun-angles and film-filter combinations. These studies showed the feasibility of using a 1/6000 scale and panchromatic film, minus blue filter, stereo coverage. A green background was desirable.

The 1967 experiment, using both aerial photography and ground enumeration, was a test of techniques previously developed. A study area in the Sacramento Valley of California covered approximately 1000 square miles (20 miles from east to west and 50 miles from north to south). The area was divided into two basic land use types--predominantly cultivated farmland, and predominantly rangeland. Sixteen area sampling units (segments) were selected at random out of each stratum but the size of the range segments were limited to approximately three square miles. Enumerators interviewed land operators to obtain livestock, inventory numbers by species and data to classify each field into one of four "domains." The domains corresponded to the degree to which remote sensing was believed to be feasible because of structures or ground cover offering varying amounts of concealment to livestock. Aerial photographs were obtained as soon as weather permitted after enumeration. Air-to-ground communication allowed teams to observe and make livestock counts in selected fields simultaneously with flight coverage.

Analysis of the results indicate that comparable inventory numbers are obtained by ground enumeration and photo interpretation except for domains where buildings, manmade shades or trees obscure part of the animals from aerial view.

Counts from aerial photos of cattle and sheep tended to be greater than the ground enumeration for the cultivated segments. However, the aerial counts for the same species were not as large as the ground enumeration in the range segments. Most of the important differences between image counts and ground data methods are associated with animals hidden from the camera or animals grouped closely together. Range areas have the additional problems of background clutter and large numbers of photos. Ground data for range segments appeared less accurate than for the cultivated segments. Large scale color photography is necessary when animals are bunched or when it is desired to detect calves, lambs or breed of animal.

3. Survey Operation

Areas for this study are the June Enumerative Survey segments in the four county area of Twin Falls, Minidoka, Jerome and Cassia Counties. This area was selected as it contains both cultivated and rangeland segments. It presents most of the anticipated problems associated with an operational survey.

The June Enumerative Survey question has been modified to collect some additional information which will permit domain classification and will give inventory numbers by species for each "field." Dates of enumeration are the same as for the regular JES in Idaho. Early completion of enumeration is desirable.

As soon as enumeration is complete, a sample of segments and fields will be selected for aerial coverage. Flights will be made as soon as weather permits after the conclusion of the June Enumeration.

Ground "truth" observations will be made in selected fields simultaneously with photographing.

After flights have been completed, a reenumeration of the segments photographed will be made to update the JES data to time of flight.

4. Enumeration of Special Items--Idaho Survey

Items 1 through 5 and 45 through 50b in Section A of each Part A must be asked and the response indicated for every field. These items are identified with an asterisk (*). Entries in item 45 through 50b will be used by the editors to classify each field into a "domain" which is intended to represent the difficulty of seeing animals.

In Section C of each Part A, questions are asked for cattle in the tract and on adjoining land. For the special survey, in addition to item 1 through 6 for cattle, items 7 through 10b are asked for calves born, sheep and lambs, horses and hogs inside the tract fields and on adjoining land.

Following is a discussion of items 45 through 50b of Section A and items 7 through 10b of Section D.

Section A - Acreages of Fields and Crops in Tract

45. MANMADE COVER in field: Houses, barns, sheds, corrals, feeders, etc.? YES ( ) NO ( )

Determine if there are any manmade structures in the field that could possibly offer concealment or confine livestock so they would be difficult to see in a photograph. These can be buildings or structures that livestock could enter or they could be next to and be obscured by shade or overhang. Check YES or NO.

46. If YES to item 45, may any of these structures by used to house or enclose livestock? YES ( ) NO ( )

Should manmade structures be located in the field, find out if they are used to house or enclose livestock; a barn, shed, corral, or any structure that livestock may enter and can leave only if released. Check YES or NO.

47. TREES or BRUSH in the fence line or border? YES ( ) NO ( )

Consider only the fence line or border of the field; disregard growth in the balance of the field. This can be plantings or wild growth in the border or fence line. Brush may be considered to be a woody type plant two feet or more in height with some type of overhanging limbs which would provide shade for animals. Check YES or NO.

48. NATURAL COVER INSIDE the field; trees or brush? YES ( ) NO ( )

The previous item 47 asked about trees and brush in the border or fence line of the field. Item 48 requires that the rest of the field be considered. Fields with natural cover inside the field will likely be range or pasture land. Do not consider weeds and grasses as natural cover. Brush may be considered to be a woody type plant two feet or more in height with some type of overhanging limbs which would provide shade for animals. Check YES if the growth of trees or woody type brush is thin and scattered, in groves, or heavily wooded. An orchard will require a YES checked. Check NO for no cover inside the field.

49. If YES to item 48, what PERCENT of the field is covered? Enter percent (%). This would be the percentage of the ground area in the field that would be obscured if it could be viewed from directly overhead, as in an aerial photograph. Exclude trees and brush in the fence lines and borders. Enter the operator's best estimate of the percentage of area covered.

50. ARE THERE ANY LIVESTOCK IN THIS FIELD NOW?

A YES will be checked should there by any livestock other than chickens in the field at the time of interview, regardless of ownership. Check NO if there are none.

a. If YES, will any livestock be moved OUT of this field within the next three weeks? Check YES or NO. Should there be livestock in the field now, this question will give an indication that they could be moved out before the time the aerial photograph is made. The present intentions of the operator will be helpful in evaluating the photographs.

b. If NO, will any livestock be moved INTO this field within the next three weeks? Check YES or NO. Again, the intentions of the operator are necessary should there not be any livestock in the field now but some may be moved in.

In both "a" and "b" the operator's estimate of what he intends to do may require some probing questions and time to think about it.

Section D - Livestock and Chickens on Tract

To meet the requirements of the special aerial photography, it is necessary that livestock be located specifically by field at the time of interview. Additional questions in Section D make it possible to obtain a count by species of the livestock within each field. Do not overlook livestock at the farmstead, in buildings, corrals or pens. Questions asking for a simple age breakdown will allow the relative size to be determined. In photographs, mature cows will be larger than calves, ewes larger than new lambs, etc. Also, we may be able to count mature stock accurately but be unable to see and count young animals. Follow item 1 through 5 at the top of the page regarding locations of livestock on the tract and on adjoining land. Item 7 through 10a are asked for each field just as item 1 through 6. Instructions for this part of Section D start on page 72 of the interviewers Manual.

7. Of the CALVES, how many were BORN since January 1, 1969? Refer to the cattle and calves weighing less than 500 pounds reported in item 4d and in the field at the time of interview. This will give a count of these younger animals expected to be smaller on a photo.

8. SHEEP and LAMBS of all ages? Enter the total of all sheep and lambs of any ages in the field, regardless of ownership.

   a. Of the LAMBS, how many were born: During January and February 1969? From March 1, 1969 to now? Obtain the number of lambs in each age group.

9. HORSES and PONIES of all ages? Regardless of ownership, enter the number of horses and ponies of all ages in the field.

   a. Of these, how many were BORN since January 1, 1969? Report the colts and foals born since January 1, 1969. These would appear smaller on photo than would mature animals.

10. HOGS and PIGS of all ages? Determine the total number of hogs and pigs of all ages in the field regardless of ownership. Be sure to include all sows, boars, young pigs, unweaned pigs, feeder pigs, etc.