METHODS OF ESTIMATING DOVE KILL

by

D. G. Chapman, W. S. Overton and A. L. Finkner

Institute of Statistics
North Carolina State College
Mimeo Series No. 244
For limited distribution

October 1959
METHODS OF ESTIMATING DOVE KILL

by

Douglas G. Chapman, W. Scott Overton and Alva L. Finkner

In the over-all management of the mourning dove it is necessary that reliable data be available regarding hunting pressure and harvest over the region in which dove hunting is practiced. Hunting and harvest data are now available from only a few isolated states. In the interest of developing procedures by which harvest data can be estimated, a one year research project was sponsored jointly by the Wildlife Management Institute, the Welder Wildlife Foundation, the United States Fish and Wildlife Service, and the Institute of Statistics, North Carolina State College. The present report covers the work accomplished by this project.

The objective of the present study is an investigation and evaluation of methods of determining harvest and hunting activity particularly with regard to the mourning dove, and subject to the following restrictions:

1. Estimates are to be comparable from state to state and from region to region. As vastly different license structures exist in the various states, methods must either be independent of licensing, or must provide corrections for this.

2. Regional estimates must be economically feasible when only one species (Dove) is involved.

3. The feasibility of state estimates, from the standpoint of economy, may depend upon securing information for more than one species simultaneously, for example, deer, turkey, quail, squirrel, doves,
rabbits and ducks. Estimates on doves must be considered here subject to the restriction that comparability of estimates be maintained from state to state.

Report of Work: The first item of work undertaken was a survey of kill inventory methods being used by the various states. In October, 1958, a letter was sent to all of the states, Alaska, Hawaii, and Puerto Rico, requesting information on methodology of surveys being used and basic research in methodology. A follow-up request was sent to states not answering, and several states were written for further information regarding interesting aspects of their work. The large volume of material resulting from this phase was carefully perused and is summarized by state in the appendix. General aspects of these results are discussed under the section dealing with results.

In the present report, working definitions of a frame are established, and the possible frames discussed and evaluated. The various methods of obtaining information are also discussed, along with the sources of error inherent in them. From these frames and methods of obtaining information, a number of sampling systems are developed, of which five are discussed in some detail. Two of these systems are retained, and recommended for operation. These two systems are discussed fully, and details of operation (where possible) presented, with formulae for estimates and estimated variance of estimates.

In selecting and evaluating these sampling systems, it is not possible to make exact comparisons for several reasons. First, materials have not been assembled, and one cannot define accurately the difficulty and cost of selecting the samples. It is not yet possible to even decide what sampling procedure is the best in the case of one system (telephone frame) recommended for operation. Secondly, field sampling is included in both recommended systems, and it is not
known what the cost-precision relationships here will be, nor to what extent this aspect will affect the total estimate.

These comments point up further work to follow. It is recommended that the following jobs be considered for the near future.

1. Assembly of materials and development of the license frame. This involves a detailed description of license status and availability of licenses for all states in the harvest region. It also involves a decision as to whether a particular state should be included in this frame or the telephone frame.

2. Assembly of telephone sampling materials and development of a specific sampling procedure for this frame for all states in the harvest region but not in the license frame.

3. Intensive evaluation of the field sampling method. An entire system of sampling must be developed here, and it might possibly have to be geared to the sampling system used in the primary stage. Sample size (in area and time) must be determined and procedures devised for selecting the sample (in space), as well as locating it on the ground.

Discussion of the problem.

We start with the premise that the estimation of harvest and hunting pressure must be based on sampling procedures. Thus the problems that must be studied are development of an adequate sampling frame, determination of the method of sampling, and validation of the proposed procedure. We must distinguish between procedures which may be used for experimental studies and those which are feasible on an operational basis. The study must lead to operational procedures, but at the same time it is necessary to retain procedures which may be important tools in small scale experiments, even though
they are not operationally feasible on a large scale.

What is a frame? Deming (22) states that, "The frame in some manner or other provides an identifying list of the N sampling units that compose the universe." In our case, the universe will generally be defined as the total number of dove hunters in the region of interest, although modification of this definition will sometimes be necessary. Too, we shall broaden the definition of a frame to include an incomplete listing of the sampling units that compose the universe.

What constitutes an adequate frame? It is clear that any frame that includes all dove hunters is adequate in that it is possible to estimate total dove hunting pressure and kill from such a frame. When dealing with a single state, one might be willing to ignore kill by unlicensed hunters and thus consider a frame of licensed hunters as adequate, which amounts to redefining the universe of interest. As indicated in the objectives, vastly different license structures occur in the various states, with different groups of persons exempt from purchasing licenses. Comparison of state estimates based on license structure, and combination of such data from a group of states, involves different definitions of universes. Hence, such a frame over a region is here considered inadequate.

Also to be considered in determining the adequacy of a frame are certain aspects of the use to which the data are to be put. The dove researchers with whom these problems were discussed at Louisville (Southeastern Conf., 1958) felt that estimates of dove kill were desirable by geographic and time strata, so a frame not allowing such stratification would be inadequate from this point of reference. Also, one would hesitate to attempt to estimate total kill and hunting pressure from a bag-check due to the difficulty in sampling; that is,
the difficulty in developing a frame and constructing a probability sample. However, the estimation of ratios is much less difficult, and the construction of an adequate frame less formidable. More will be said about such estimates later.

An adequate frame is not necessarily feasible, as cost of obtaining estimates may be too great. This consideration is both absolute and relative, as any estimates to be considered must cost no more than one is willing to pay for them, and as cost is the basis by which one must choose between two adequate frames or sampling systems. Also, as indicated earlier, adequacy is relative to a certain degree, and in selecting a frame one must weigh adequacy and feasibility considerations simultaneously. Thus a certain amount of judgement is involved, although there should ideally be some means of evaluating consequences of whatever assumptions must be made.

So far we have considered only simple frames, whose adequacy depends primarily on completeness and secondarily on characteristics relative to the estimates desired. This concept can be extended readily to include two or more simple frames, each incomplete, but each of which covers the segment of the universe not covered by the others. Simultaneous use of two such frames is much simpler if they are mutually exclusive than if each includes a segment of the universe also included in the other. Also it is desirable that characteristics relative to estimates be the same in each sub-frame. For this report we shall refer to these as multiple frames.

Another joint use of two frames, which shows much promise in the present project, is that of a simple incomplete frame coupled with another, ideally complete and independent of the first. These, which we will call complex frames, are suited for ratio estimation procedures. Of course, when one has a complete
frame that will provide estimates satisfactorily, then one will choose the complex frame only if it is less expensive. Also, as previously stated, it is sometimes possible to construct a complete adequate frame for the estimation of ratios, which frame is not adequate (or economically feasible) for estimation of totals. In such a case, estimated ratios can be used to expand the estimates from an incomplete frame to the desired totals.

We have now to consider the possible simple frames and their characteristics. Those under consideration can be classified as follows:

I. Complete Frames.
   A. Area household frame
   B. Area-time field sampling frame
   C. Miscellaneous lists of households, total population

II. Nearly Complete Frames.
   A. Dove permit holders
   B. Prerequisite hunting license holders

III. Incomplete Frames: Definable with respect to the Universe
   A. Hunting license holders
   B. Waterfowl stamp holders

IV. Incomplete Frames: Indefinable with respect to the Universe
   A. Telephone listing
   B. Automobile Registration lists
   C. Miscellaneous partial lists of households, farms, and other segments of the population.

I-A Area household frame. The term "area survey" has a well defined meaning in sampling; it refers to a procedure to delineate the total area to be sampled so as to choose randomly within strata or primary sampling units the occupied
dwelling units (ODU's) of the human population within the area. Such a procedure is widely used and provides a satisfactory sample of the total human population, including a satisfactory sample of the universe of dove hunters in which we are interested. Stratification and definition of larger sampling units as well as definition of ultimate sampling units require decisions that must be made for each survey.

The relatively small proportion of interviews that yield information considerably increases the cost of an area survey, and somewhat limits its application.

I-B Area-time field sampling. In association with this frame the universe is redefined. Here the universe is the sum total of dove hunting area multiplied by the time (hours perhaps) that doves can be hunted during the season. The frame then is the "list" of sample units of time and area. Note that the populations to be directly estimated from this frame are man hours of hunting and total kill, and that further extension to number of hunters and number of man days of effort require additional information.

The ideal time-area frame would be composed of small units in each of which it would be possible to observe the total number of dove hunters and count the number of doves taken. Such a frame is clearly impractical as such small units of area would be difficult to delineate and more difficult to locate exactly in the field. Also, the presence of an observer would very likely influence the amount of hunting. Thus it is felt that this frame must be restricted to the field bag-check method of interview.

Several problems in estimation are yet unsolved, and at the present time we will consider this frame of use only in providing ratios: kill per hour and day, kill per licensed hunter, kill per unlicensed hunter, licensed hunters to
unlicensed hunters, etc. This is not to say that problems do not remain in estimation of these ratios, but that they are less important than those involved in estimating totals.

Also, in estimating ratios, the delineation of sample units need not be nearly so rigid as would be necessary to estimate totals. The difficulty of identifying an individual hunter with a particular unit of area leads one to the device of associating the hunter with the unit of area in which he parked his car. The logical extension of this line of thought is to the use of roadsides and potential parking areas as sampling units. One very practical difficulty arises -- it is likely that the ratio of licensed to unlicensed hunters would be biased as the sampling units would not include hunters who walked from home.

For these reasons it is likely that the "sweep" method of contacting hunters will produce the best results. Under this method the sampling units will be constructed in such a manner that the observer can "sweep" through a unit interviewing all hunters. Such contacts can be randomized in time and should provide satisfactory ratios.

This frame is ideal from the standpoint of obtaining information by geographic regions and by time periods throughout the season. In addition, it is possible to collect biological data concurrently with the kill data.

I-C Miscellaneous lists. This item is included as suggestions have been made regarding use of lists of residences, independent of residents. Also possible frames are complete lists of the human population, such as could be obtained from census records. These records are not available for such use and no other suitable such lists have been found. These may exist, however, for small scale investigative surveys.
II-A Dove Permit Holders. As mention has been made of the possibility of requiring every dove hunter to purchase a dove stamp, consideration should here be given to the use as a frame of names and addresses available from such purchase. For purposes of this evaluation, it is necessary to indulge in a certain amount of conjecture regarding this frame. We assume a structure identical to the frame of waterfowl hunters which is provided by the sale of waterfowl stamps. We also assume that persons under 16 years of age will not be required to purchase such a permit in order to hunt doves, hence the category "Nearly Complete."

Sample post offices will provide incomplete lists of names and addresses of persons purchasing permits, if we may again judge from the waterfowl survey. Degree of completeness ranges from nearly 100 per cent to zero on the basis of individual post offices. There is also wide variation in completeness from state to state, with the result that this frame also poses problems of state to state comparability. The size of the universe is closely approximated by the frame, but the "effective" frame is incomplete, requiring assumptions about the portion not represented by the available names. It is assumed that improvements can be made; that greater effort will result in more complete representation of the universe.

For administrative reasons, it is likely that a sampling system using this frame will be similar to that of the waterfowl survey, with post offices as sampling units. As pointed out in the Institute report (3) regarding variances of the estimates of waterfowl kill, certain changes in the selection of sample post offices appear to be desirable, among which stratification by size of post office is foremost.
Prerequisite hunting license. The idea of a prerequisite hunting license has come up several times in the last few years, particularly with regard to the problem of estimating the actual number of hunters as opposed to the number of licenses purchased. It is clear that lists of holders of such a license would have many advantages as a frame for a wide variety of surveys, and the expense of refining such a frame would be defrayed by several potential applications, rather than by a single survey, as with the duck stamp or the proposed dove stamp. On the other hand, larger samples will be necessary to obtain the same accuracy due to the high rate of nonparticipation with regards a single item.

The frame of state hunting license holders probably ranges, from state to state, from nearly complete to very incomplete. Most states have regulations allowing some hunting on homesteads without licenses (Texas does not require a license for small game in one's home county), and the degree of incompleteness is then determined by the number of hunters who still buy a license in order to hunt elsewhere. This is further complicated by the structure of the licensed group. When separate and independent licenses are required for different species or groups of species, it may be necessary to eliminate part of the potential frame of licensed hunters as the amount of overlap is unknown and difficult to estimate. We will confine present consideration to purchasers of a single license, or of two or more mutually exclusive licenses covering the same species or group of species (for example, state licenses and county licenses) between which the overlap can be considered insignificant.

This frame also has a certain amount of incompleteness due to illegible or incomplete names and addresses or to unobtainable carbon copies. Changes in administrative and clerical procedures can do much towards eliminating this source of trouble. More will be said about this when discussing the problem of
non-delivery in mail surveys, which is very closely related.

As indicated earlier, a major difficulty in the use of the state license frame is due to the difference in completeness from state to state.

III-B Waterfowl stamp holders constitute a frame, comparable over states, which reflects a definable segment of the universe of dove hunters. It is clear that a large percentage of dove hunters will not be included in this frame, and also that an appreciable percentage of the persons included in the frame will not be dove hunters. Thus, a relatively large sample will provide relatively low accuracy estimates of a portion of the dove kill and hunting pressure. Also, this frame has the same general characteristics with regards to unavailable names and addresses that lie within the sample post offices that were discussed under Frame II-A.

IV-A Telephone frames are not widely used because it is difficult to evaluate the assumption that the attribute being measured is independent of the possession of a telephone. Also, definition of the portion of the universe represented by a telephone frame is difficult and cannot be made in terms of natural divisions or categories of the universe itself.

It is clear that this frame is unsuitable by itself; that it does not constitute an adequate simple frame. Thus consideration is limited to use in conjunction with one or more other frames. As the telephone frame cannot be defined in terms of the universe, the possible mutually exclusive frames are limited to definition in terms of not possessing (or being contactable by) a telephone. This does not appear too rewarding, and we will consider only complex combinations. If the telephone frame is used as the basis, the estimate that will be expanded by information obtained from an independent frame, then the telephone frame must be defined in such a way that all persons contacted in the course of the secondary
survey can be simply and accurately identified by this definition.

Use to estimate ratios for expansion of estimates obtained from other sources will involve assumptions about the relationship between the hunters defined in the telephone frame and those not defined in it. The assumptions cannot be evaluated at present and this use will not be investigated further.

We have now to develop a definition of a telephone frame that will be satisfactory for use as a basis in a complex frame. Some possibilities are: 1, persons in whose name a telephone is listed; 2, persons living in a household in which there is a telephone; 3, persons who have access to a telephone. At present, it is felt that (1) is the most satisfactory, even though it eliminates some information available from a telephone interview.

IV-B The use of automobile registration lists as a frame also offers promise in providing an estimate that can be expanded by an auxiliary ratio. This has been used in at least one instance (15) and has very much the same potential as the telephone frame. One additional difficulty is multiple ownership of vehicles, the solution of which would depend on the filing system used in the particular state.

IV-C A number of incomplete frames may be developed from files of government and state organizations such as the Agricultural Stabilization and Conservation Service (ASC), the Soil Conservation Service, Rural Electrification Association, and many others. As these all have the same limitations of use as frames IV-A and IV-B, it is likely that their use will be restricted to specialized or local studies.

Errors occurring in surveys.

All systems of obtaining hunter harvest information have in common, to varying degree, several sources of error, even when the frame adequately
represents the universe. These may be broadly classified into sampling errors, response errors, and non-response errors. Sampling error is the failure of the sample to reflect exactly the characteristics of the universe which it represents. Response error is the failure of the reported characteristic to be equal to actuality. Non-response error is the failure of the characteristic of the respondents to be equal to the characteristic of the non-respondents. It is caused by the correlation between the attribute being measured and the success of obtaining the measurement, in the presence of incomplete response from all persons included in the sample.

The usual statistical computation of confidence limits takes account only of the sampling errors. Under reasonable assumptions regarding distribution and sampling probability, and assuming the other errors do not exist, it is possible to provide unbiased estimates of the mean, and to induce the variance of the sample from the variance within the sample. Then one can make statements about the confidence limits of the estimates, and make further statements regarding the probability that these statements are correct. The presence of the other two classes of errors often drastically reduces the usefulness of such intervals, and it is with these errors that we will be most concerned.

Little is known about the nature and magnitude of response errors in game kill surveys. Atwood (5) provides us with the only information on the nature of these errors, although his study and studies in California (Ben Glading, personal correspondence) and Rhode Island (21) provide information on their magnitude. The subject has hardly been touched, however, and much needs to be learned about these errors.

Response errors can be classified as follows:

1. Memory. A person's ability to recall the amount of game killed is clearly a function of time, and is also a function of hunting practices and habits which
influence the impression his kill makes. For example, it is common practice for
hunters, at least in Florida and Minnesota (43), to pool the party bag --- to
hunt until the "party" limit is reached --- rather than to observe the bag limit
as individuals. How then would these hunters report their daily bag, and their
seasonal bag, if questioned individually immediately after such a hunt?

2. **Interpretation.** There are several causes of interpretation error. Reporting
"take home" kill, rather than the actual amount killed by the individual, is
closely associated with the inability to remember individual kill, as in the
previous item. This would be all right if each person in the party reported
"take home" kill, which is a procedure used to evident advantage in Minnesota (43).

Despite all efforts, it seems that some misinterpretation of questions is
inevitable. This can be minimized by careful phrasing, thorough testing, and
care that instructions are clear and evident. Particularly bothersome are the
report of game taken outside an area of special interest, the father reporting
the sum of his and his son's kill, and the hunter reporting the sum of his party's
kill. Such reports are detected only by accident, as when the respondent happens
to write a note indicating what he has reported.

3. **Falsification.** Deliberate or unconscious falsification of reports can result
from the desire to hide knowledge of illegal kill, to show lack of cooperation
with a game department, or to be helpful. Some respondents have the firm belief
that the more they report the more helpful they are. Falsification can also
result from the well publicized desire to be successful --- the prestige bias
impulse.

4. **Incompleteness.** Items not filled in, or improperly filled in, are trouble-
some. It is necessary to make assumptions regarding such omissions, applying
correction procedures or allowing the sample response to vary with each item,
considering these to be non-response.

5. **Rounding.** Simple inaccuracy, or rounding to multiples of five, or a dozen, or even numbers, or what have you, introduces a certain amount of bias due to the non-linear configuration of the frequency curve. If this curve is concave upwards, as are the usual kill data curves, then simple rounding will produce positively biased results. The magnitude of this bias is unknown, but can (and should) be investigated under generalized frequency curves and simple patterns of rounding. Such study would also lead to development of models that would be of value in studying all response errors.

Atwood (5) studied differences in reported kill (from post season mail questionnaire) and recorded kill on several waterfowl hunting areas. He found that the net effect of these differences was closely approximated by certain adjustment procedures involving the frequencies toward which rounding occurs, although no functional relationship between these procedures and the observed response errors was established. There are many implications of these results, and much further work is needed.

Non-response error was defined as that caused by the correlation between the attribute being measured and the success of collecting the data. Of course its presence is dependent on non-response; if there is no non-response there is no error due to this source, no matter what the correlation. It follows that the potential error is a function of the magnitude of non-response as well as a function of the correlation between the attribute and collection success. In the latter respect, one suspects greater correlation in voluntary response systems, such as mail surveys, than in systems in which lassitude or disinterest can play no part in response. Even then, when non-response occurs in any type of survey, one cannot rule out the possibility that this error exists.
There is much conflicting opinion in the wildlife field on this subject of non-response error. Much of this may be due to the fairly common practice of accepting the null hypothesis; a test for bias of non-response is non-significant, so it is concluded that there is no bias of non-response. One must remember that there are infinitely many alternative hypotheses that also would not be rejected by this particular test, all of which lie within an interval which can be described. Thus from a single test, or from a group of tests, one may make a statement that the bias of non-response is less than a certain magnitude, and make a further statement about the chance of this statement being in error. One might consider such an estimated magnitude to be inconsequential, but one cannot prove that it is zero.

The definition of any given error as "inconsequential" is also quite relative, as under a different set of circumstances or in a different application such an error magnitude might not be inconsequential at all. Even when it is shown under a given set of conditions and for a given set of data that the bias of non-response is inconsequential, it is risky to then consider the issue closed and assume that the bias will be constant under all other conditions and for all other sets of data. Thus it is highly desirable that estimation procedures be used that account for this characteristic. Overton (manuscript in preparation) has been working on this for several years, and some of his results are presented in the section of this report dealing with estimates.

Methods

Methods of obtaining information are many and varied, but fit nicely into three categories: personal interview, telephone interview and self-administered questionnaires.

The personal interview is here defined as the face to face questioning of a
sample respondent by an interviewer, who records the answers. This method is characterized, ideally, by the virtual elimination of incompleteness, by the minimization of misinterpretation and non-response, and by little direct influence of participation and success on the likelihood of response.

The telephone interview is here defined as a personal interview conducted over the telephone. One expects the telephone interview to have much the same characteristics as the personal interview, with some lessening of the influence of the personal contact.

The self-administered questionnaire, as here defined, includes all systems in which the respondent reads a list of questions and writes down the answers; it includes mail surveys, license stub reports, etc. Here the non-response errors are most critical, and the errors of misinterpretation and incompleteness are most prevalent.

It is not possible to describe the characteristics of these methods relative to memory, falsification and rounding errors. It is conceded that such knowledge would be useful, and that these errors should be investigated in relation to the methods of obtaining information. As all of the methods contain several sources of error, it is clear that research in this area must be conducted in such a way that these errors can be identified and studied individually as well as en toto.

Sampling Systems

From the described frames and methods of obtaining information, one can assemble a great variety of sampling systems. For reasons of space we shall list only the more important, and detailed discussion will be further limited to the more feasible.

Based on simple frames:

1) I.A.I. Area sample with personal interview.
2) II.A.1. Sample of dove stamp holders with personal interview.

3) II.A.3. Sample of dove stamp holders with mail survey.

4) II.A.3-1. Sample of dove stamp holders with mail survey and interview followup.

5) II.B.1. Sample of master license holders with personal interview.

6) II.B.3. Sample of master license holders with mail survey.

7) II.B.3-1. Sample of master license holders with mail survey and interview followup.

Based on complex frames:

8) III.A.1/I.B.1. Basic estimate from interview of sample of state hunting licensees expanded by ratios from interview of hunters in the field.

9) III.A.3/I.B.1. Same as (8), but with mail survey, instead of interview, of sample of licensees.

10) III.A.3-1/I.B.1. Same as (9) with interview followup of non-response.

11) III.B.3/I.B.1. Basic estimate from mail survey of sample of waterfowl stamp holders, expanded by ratios from interview of hunters in the field.

12) IV.A.2/I.B.1. Basic estimate from telephone interview of sample of telephone owners, expanded by ratios from interview of hunters in the field.

13) IV.B.3/I.B.1. Basic estimate from mail survey of sample of automobile registration, expanded by ratios from interview of hunters in the field.

These and other sampling systems easily deducible from these may be of value in investigation of certain aspects of the overall field of kill survey methodology. However, it now looks as if a very few can be considered as operational systems for the routine collection of data, these being 3, 6, 9, 11, 12, and 13. As No. 13 has much the same general characteristics as No. 12, it will not be discussed fully.
Table 1. Comparison of several features of the primary frames of sampling systems under consideration, with reference to the universe of dove hunters.

<table>
<thead>
<tr>
<th>Sampling system</th>
<th>3</th>
<th>6</th>
<th>9</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary frame</td>
<td>Dove Stamp</td>
<td>Master License</td>
<td>State License</td>
<td>Waterfowl Stamp</td>
<td>Telephone List</td>
</tr>
<tr>
<td>1. Percent of universe included in the primary frame</td>
<td>95</td>
<td>95</td>
<td>95-50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>2. Effective frame: percent of frame available and usable</td>
<td>75</td>
<td>95</td>
<td>90</td>
<td>75</td>
<td>95</td>
</tr>
<tr>
<td>3. Response: percent of sample</td>
<td>65</td>
<td>65</td>
<td>65</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>4. Participation: percent of sample</td>
<td>95</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>5</td>
</tr>
</tbody>
</table>

In Table 1 are presented for purposes of comparison the anticipated percentage of dove hunters included in the various primary frames, and response rates and participation to be expected from these frames. Some of these figures are highly speculative, and should not be considered more than a general guide to the relative merits of the systems under consideration. Systems 3 and 6 compare favorably with systems 9, 11 and 12 on the basis of lines 2, 3 and 4, hence seem the best of the lot by virtue of requiring no secondary (field sampling) frame. However, neither of these systems actually exists at present as the dove stamp and the master license are merely suggested possibilities.

Sampling system No. 9, based on a primary frame of state licenses, remains as the best system presently available. An immediate objection arises to the use of state licenses as a basis of a sampling system, as license lists in some states are not available and in others are available only at considerable expense.
Therefore it is necessary to consider one of the remaining systems for use in states in which the state licenses are not available. System No. 11, based on the waterfowl stamp, has the desirable feature that a sample is already available from the waterfowl surveys, but this sample is small, relative to the accuracy needed, as participation is low. Participation is also low for system 9, and lower yet for system 12, but in both of these cases the sample size can easily be expanded to provide the necessary accuracy, while sample size of the waterfowl survey is fixed. It is conceivable that the waterfowl stamp sample might in a given situation be more satisfactory, but the telephone frame will here be considered due to its greater flexibility.

Discussion of proposed system.

The sampling system that we have left is as follows. For states having available a usable set of names and addresses, the basic survey is a mail sample of licensees. For states not having available such a list of licensees, the basic survey is a telephone interview of a sample of people in whose name a telephone is listed. In all states, supplementary information will be collected by use of the area-time field sampling frame, which information will consist of ratios of kill by unlicensed hunters to kill by licensed hunters, number of unlicensed hunters contacted to number of licensed hunters contacted, or other pertinent ratios. In the case of the use of the telephone survey in the particular state, all of these ratios will be based on the ownership of a telephone.

It is desirable here to clarify definitions used in reference to the various aspects of the complex frames to be employed. The frame of license holders, or telephones, has been referred to as the primary frame. From this frame is estimated total kill, for example, which in the terminology of ratio estimation is the "auxiliary population." The area-time field frame is the secondary frame,
from which is determined the ratio by which the auxiliary population is expanded to the total population. This differs from the usual ratio estimate only in that the auxiliary population is itself estimated. We have also used the term "basic frame" in reference to the primary frame, and "supplementary information" in reference to the ratios estimated from the secondary frame.

The definition of the primary frame with respect to the secondary frame presents several difficulties. It is clear that if we define the primary frame as the license holders of the current season, then it must be possible to identify each hunter contacted under the secondary survey with respect to this frame. The difficulty here is that many states have dove seasons starting before the regular season, and that persons not required under law to purchase a license to hunt doves might purchase one, at a later date, in order to hunt something else. Thus they would be in the primary frame, but would not have been so identified when checked. The only apparent solution to this is to use the frame of the previous year's license holders, and to ask each person checked in the field if he purchased a license during the previous year. The telephone frame will not present this difficulty, but has some of its own.

A further difficulty in definition of the primary frame is caused by multiple licensing. Many states have license structures which require different licenses for different game species. Thus a hunter may have had more than one license the previous year, or he may have had one of several. In such states it will be necessary to select one type of license for the primary frame; more than one can be used only if they are mutually exclusive—if there is very little chance that a person purchasing one would purchase another. This further complicates the collection of field data, as it must not only be determined if a hunter was licensed the previous year but also determined what type or types of license he purchased.
Definition of the primary frame of telephones presents a similar problem as persons may have more than one telephone in their name. The treatment of business phones has been indicated by the original definition of the frame, i.e., all persons in whose name a telephone is listed. This definition will be extended to exclude from the frame the business phones whose listing involves a person's name. The major difficulty here is that in excluding these categories from the frame, there must be some adjustment of the total frame size. Presumably totals of residential telephones will be available from telephone companies, but if this is not the case it will be necessary to estimate from the sample the number of non-residential telephones and delete this from the total. With regards to duplication, each sample name must be checked to see if it is duplicated, and if so, dropped or left in the sample by the toss of a coin. Again, adjustment of the frame total must be on the basis of sample estimates.

As previously indicated, there are many unknowns in all aspects of such surveys. It would be undesirable to set up any sampling plan without concurrently conducting research on the many sources of error. For this reason, it is here suggested that certain "tests" be incorporated into the initial design, and that plans be made for other tests, depending on the outcome of the initial results.

It should be kept in mind that the easy availability of telephone books, the ease of drawing a sample from these books, the much more complete enumeration of the sample that is possible, and the accuracy of identification of the respondent, make the telephone survey very desirable, and careful thought should be given to the possibility of using this as the primary frame over the entire region of interest. The telephone frame should be tested during the early stages of the study.
Frame testing should be the first job to follow this report. There is no record of the telephone frame being used in this way, and it is necessary to conduct a test to determine if it will come up to expectations. Response rates, and amount of non-response, should be determined. It would also be well to substantiate the anticipated rate of participation, as in Table 1, for this as well as other frames. Testing should include assembling materials and information, and describing sources and limitations over the area of interest. The secondary frame should also be tested during this phase, both from the standpoint of developing practical sampling units and an associated method of sampling, and from the standpoint of developing a field questionnaire that will give the required information. It may be desirable to test the waterfowl stamp frame to verify the present evaluation, but otherwise tests should be limited to the telephone frame, the state license frame, and the time-area field frame.

An important aspect of frame testing involves determining the magnitude of kill by unlicensed hunters. This is necessary in two respects: field sampling must be much more intensive in a particular state if a large number of dove hunters in that state are unlicensed, and if practically no dove hunters are unlicensed, it will likely be advantageous to use the current year's licenses for the primary frame rather than those from the previous year. The latter point will be somewhat difficult to ascertain, and will involve intensive evaluation by individual state.

Much has been said about response and non-response errors, and it is certain that full reliance cannot be placed in survey results until these errors are much better understood. There should be plans devised for studying response errors and non-response errors in much the same way that Atood (5) studied these errors in estimation of duck kill. A problem is that large dove management areas do not
exist such that these tests can be made. As important as this problem is, it might be feasible to set up several areas for this primary purpose. Another problem is that extrapolation of results from study areas to statewide surveys is risky; it must be assumed that the select group of hunters using the management area have the same error patterns as the entire universe of hunters, that the act of recording kill at the check station did not make an impression on the hunters memory, etc. For these and other reasons, it seems desirable to include corrections for these errors in the "model", that is, that estimates take advantage of sample information about trends in mean response with succeeding waves, and that parallel samples be devised such that adjustments for the effect of time can be made.

Methods have been developed for extrapolating mail response data in an attempt to correct for non-response bias. A paper presenting these methods is presently in preparation. Several difficulties are involved in determining variances of these estimates, particularly when systematic or otherwise non-random selection is exercised, and when adjustments have been made for missing data. The proposed procedure involves drawing several (3 or more) independent samples, each of which is treated as a complete mail survey, and each of which provides estimates of each item of interest. Then the variance among the final estimates is used to set confidence limits on the mean of those estimates.

As memory bias is a function of time, it will be recognized that these procedures are not independent of memory bias. As has been repeatedly pointed out, these errors must be studied together, and procedures are now being studied that, it is hoped, will allow simultaneous analysis of memory and non-response errors. These procedures involve staggered surveys, the 1st mailing of one sample coinciding with the 2nd mailing of the first, etc.
Design A.

Three or more samples (the best number can be determined only by analysis of data not now available) are drawn from the state licenses designated as the primary frame. Method of sampling will not now be specified, as conditions vary widely, and different states will be best sampled by different systems. In all cases, however, advantage should be taken of any characteristics of the structure (such as different types of license, month of purchase, county of purchase, etc.) that may provide for more precise estimation. The samples are to be independent; that is, if systematic sampling is used, an independent random start should be used for each; if random sampling is used they may be drawn in any random manner.

It is essential that all drawing procedures be consistent with this definition of independence. No substitution for illegible or unusable name or address can be made, and if such are drawn in the sample, they should be pulled from the file, rather than left in. These can be combined with the non-delivery class.

Mailing should be made immediately at the close of the dove season, with consideration given to a separate survey following the two halves of split seasons where they occur. Inclusion of other species on the questionnaire will sometimes necessitate delay, although this will be infrequent when the previous year's licenses are used as a source of addresses.

In the event that a state has a regular mail survey, it may be possible to use the sample drawn for the previous year's survey. In such a case, it will certainly be advantageous to put the mailing list on punch cards before the state's survey, such as in the procedure used in Florida, because advantages of accuracy, speed, and machine operation will more than offset the additional cost of preparation. As the dove questionnaire will be short, it will be possible to utilize mailing procedures similar to those used by the Fish and Wildlife Service,
but with addresses printed by machine (say the IBM 557) from the address cards directly to the questionnaire card, which would be a self-addressed business-reply card, with the identification number of the addressee punched into it. This single card would then be inserted into a stamped window envelope for mailing. Three copies of this questionnaire could be developed at the same time, and the second and third files purged by machine before the second and third mailings. Purging would be accomplished by sorting response cards and collating against the questionnaire list.

Use of this procedure will, of course, depend on the structure of the regular mail survey being identical to that used in the dove survey, and on the use of punch card procedures. The considerable savings in cost of the dove survey will certainly justify certain modification and effort in order to make possible such procedures.

The secondary phase of Design A is the area-time field sampling of dove hunters. The definition of sampling units has been previously discussed, and it has been suggested that this phase be tested preliminary to operation of the system. There also, as previously mentioned, remain certain problems of sampling probability, which must be resolved before this system is wholly effective. Sampling units will be some measure of area for some length of time, optimum dimensions to be determined in the testing stage. Data collected will be, for each individual hunting in the s.u., type of license purchased the preceding year, doves killed and hours hunted (on day contacted), and number of days hunted during the season prior to the day on which contacted. To aid in evaluating the method, it would be well to collect other data, when feasible, such as the type of license purchased the current year and the place (county or other applicable political subdivision) of purchase of the current license. It is essential that
sampling units be defined in such a way that all hunters active at the time of checking may be contacted, or that observations can be expanded to the sampling unit total in order that the usual ratio methods be used. If this is not possible, it will be necessary to make additional assumptions regarding selection of hunters in the sampling unit and the relationship between the number of hunters per sampling unit and their success. This case will not be considered further.

In the following section are presented the suggested formulae for Design A. The total estimate from the mail survey, $\hat{Y}_T$, is,

$$\hat{Y}_T = \frac{N}{k} \sum_{j=1}^{k} \hat{Y}_j$$

$$= \frac{\hat{Y}}{N}$$

where $k =$ number of samples,

$N =$ total number of licensed hunters in the frame,

$\hat{Y}_j =$ mean estimate from the $j^{th}$ sample.

and the estimated variance of this estimate is,

$$V(\hat{Y}_T) = \frac{N^2}{k(k-1)} \sum_{j=1}^{k} (\hat{Y}_j - \hat{Y})^2$$

$\hat{Y}_j$ is estimated from the $j^{th}$ sample by fitting a quadratic equation through the origin to the three points of the cumulative mail responses, extrapolating to the effective sample size, $n_j$, by means of a tangent to the point on the curve corresponding to the third observation, and dividing the estimated sample total
by \( n_j \),

\[
\hat{Y}_j = b_{1j} + b_{2j} \left( 2X_{3j} - \frac{x_{3j}^2}{n_j} \right), \quad \text{(see footnote)}
\]  

(1)

where \( n_j \) = effective sample size for the \( j^{th} \) sample; that is, the total sample size minus non-delivery and unusable returns.

\( X_{1j}, X_{2j}, X_{3j} \) = cumulative number responding to the 1st, 2nd and 3rd mailings, respectively,

and,

\[
b_1 = \frac{\left( \sum_{i=1}^{3} \frac{Z_i}{U_{1i}} \right) \left( \sum_{i=1}^{3} \frac{U_{2i}^2}{U_{1i}} \right) - \left( \sum_{i=1}^{3} \frac{U_{2i}Z_i}{U_{1i}} \right) \left( \sum_{i=1}^{3} \frac{U_{2i}}{U_{1i}} \right)}{D}
\]

\[
b_2 = \frac{\left( \sum_{i=1}^{3} \frac{U_{2i}Z_i}{U_{1i}} \right) \left( \sum_{i=1}^{3} \frac{U_{2i}}{U_{1i}} \right) - \left( \sum_{i=1}^{3} \frac{Z_i}{U_{1i}} \right) \left( \sum_{i=1}^{3} \frac{U_{2i}}{U_{1i}} \right)}{D}
\]

where,

\[
D = \left( \sum_{i=1}^{3} \frac{U_{2i}}{U_{1i}} \right) \left( \sum_{i=1}^{3} \frac{U_{2i}^2}{U_{1i}} \right) - \left( \sum_{i=1}^{3} \frac{U_{2i}}{U_{1i}} \right)^2
\]

Before simplification, formula (1) is as follows,

\[
\hat{Y}_j = \frac{1}{n_j} \left[ b_{1j} X_{3j} + b_{2j} X_{3j}^2 + (n_j - X_{3j})(b_{1j} + 2b_{2j} X_{3j}) \right]
\]
\[ U_{11} = X_1 = \text{number responding to first wave.} \]
\[ U_{12} = X_2 - X_1 = \text{number responding to second wave.} \]
\[ U_{13} = X_3 - X_2 = \text{number responding to third wave.} \]
\[ Y_1, Y_2, Y_3 = \text{cumulative reported totals to 1st, 2nd and 3rd wave respectively.} \]
\[ Z_1 = Y_1 = \text{total reported for first wave.} \]
\[ Z_2 = Y_2 - Y_1 = \text{total reported for second wave.} \]
\[ Z_3 = Y_3 - Y_2 = \text{total reported for third wave.} \]
\[ U_{21} = X_1^2 \]
\[ U_{22} = X_2^2 - X_1^2 \]
\[ U_{23} = X_3^2 - X_2^2 \]

It will be noted that in the final form of the estimation equation,

\[ \hat{Y} = b_1 + b_2 \left( 2X_3 - \frac{X_2^2}{n} \right) \]

the term on the right is a correction for deviation from linearity, and when the quadratic component approaches 0, the estimate approaches the linear slope. Now our only justification in selecting this model over the direct quadratic extrapolation

\[ \hat{Y} = b_1 + b_2 \frac{x}{n} \]  \hspace{1cm} (2)

is that the latter estimator is less stable, and in preliminary tests has given estimates with greater variance. Each of these (1 and 2) will provide correction
for deviation from a linear relationship between reported totals and number responding. If no such deviation occurs—if the observed relationship is linear—there is no evident bias of non-response and the present estimator will be simply the linear regression coefficient, \( b_1 \), as \( b_2 \) will be zero. In this case, \( b_1 \) represents the slope of the straight line drawn through the origin and all three points, and is identical to the simple sample mean.

It is clear that if deviations from linearity do occur, as they frequently do, the use of this model will allow much more accurate comparison of results at intermediate points, particularly when the comparisons involve different response levels. Also note that the method is independent of the nature of the curve: reported activity may increase, or decrease, with increased response. The sole limitation is the usual one in approximating an unknown functional form with a polynomial, and it is difficult to evaluate such an approximation when sampling errors are involved. Nevertheless, this model is certainly much safer than the usual linear model when it cannot be assumed that the functional form is truly linear.

The results involving the estimator of \( \hat{Y} \) are not a product of the present project, but were developed by the graduate assistant while in the employ of the Florida Game and Fresh Water Fish Commission. These have not yet been formally published, but are presented here because of their direct bearing on the present report.

The complete estimate, expanded to include all hunters, is \( \hat{T} \),

\[
\hat{T} = (\hat{Y}_T)(\hat{R}) .
\] (3)
The formula for \( \hat{R} \) varies with the item being measured, and also depends on certain characteristics of the data gathered. We will designate the ratio appropriate for expansion of total kill as \( \hat{R}_1 \), the ratio for man days as \( \hat{R}_2 \), and that for hunters as \( \hat{R}_3 \). Further, different estimators of \( \hat{R}_1 \) will be designated \( \hat{R}_{11} \) and \( \hat{R}_{12} \). Let us consider the case in which the mean length of time hunted by the licensed hunters contacted is equal to the mean length of time hunted by the unlicensed hunters. By "equal", we can arbitrarily specify some difference which will be considered inconsequential.

\[
\hat{R}_{11} = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i} + 1 = \hat{R}_{11}' + 1,
\]

where

\( y_i = \) Total kill by unlicensed hunters in the \( i^{th} \) s.u.

\( x_i = \) Total kill by licensed hunters in the \( i^{th} \) s.u.

and,

\[
V(\hat{R}_{11}) = \left(\hat{R}_{11}'\right)^2 \left(\frac{s_y^2}{\bar{y}} + \frac{s_x^2}{\bar{x}} - \frac{2(s_{xy})}{(\bar{x}\bar{y})}\right)
\]
When we cannot consider the mean length of time hunted by the two groups of hunters to be equal, then the usual estimate of the ratio of kill by one group to kill by the other group is no longer valid. It is then necessary to estimate the ratio in another manner. The following estimator is somewhat involved, but seems to be satisfactory, and can easily be computed on the IBM 650. If it proves to have good characteristics, this estimator should always be used, regardless of the comparison of mean length of time hunted.

Let

\[ \hat{R}_{12} = \frac{\hat{Y}_1 + \hat{Y}_2}{\hat{Y}_2} = \frac{\hat{Y}_1}{\hat{Y}_2} + 1 \]

where

\[ \hat{Y}_1 = \sum_{j=1}^{k} b_{1j} h_{1j} \]
\[ \hat{\gamma}_2 = \frac{1}{k} \sum_{j=1}^{k} b_{2j} h_{2j} \]

and

\[ h_{1j} = \text{the number of unlicensed hunters contacted during the } j^{\text{th}} \text{ time period.} \]

\[ h_{2j} = \text{number of licensed hunters contacted during the } j^{\text{th}} \text{ period.} \]

\[ b_{1j} = \text{the least squares estimate of the mean kill per unlicensed hunter for the } j^{\text{th}} \text{ time period.} \]

\[ b_{2j} = \text{the least squares estimate of the mean kill per licensed hunter for the } j^{\text{th}} \text{ time period.} \]

This analysis assumes that all time periods have the same number of sampling units selected at random, and that therefore the total number of hunters observed during each time period is a correct weight for the estimated rate of kill for that period. If the number of s.u.'s per period varies, then the appropriate weights will be the mean number of hunters per s.u. per period.

By using least squares, it is possible to estimate the \( b \)'s more precisely, since a single observation is defined as

\[ y_{ijk} = p b_{j} + b_{j-1} + b_{j-2} + \cdots + q b_{j-z} + \varepsilon_{ijk} \]

where

\[ p = \frac{\text{length of time hunted during the period checked}}{\text{length of period}} \]

\[ q = \text{proportion hunted of first period in which person hunted.} \]
z = number of periods during which the hunter has hunted prior to that in which checked.

\[ Y_{ijk} = \text{cumulative kill of the } k^{th} \text{ hunter in the } i^{th} \text{ sampling unit and the } j^{th} \text{ time period, i.e., the number of doves he has at the time checked.} \]

Here it will be noted that the total length of time the person hunted before being checked is equal to \( L(p+q+z-1) \), (where \( L \) is length of period). This definition will cause no difficulty so long as the hunter has hunted only during consecutive periods, but it is quickly recognized that the definition of this vector is difficult if he has hunted intermittently. The effect of this should be evaluated during the testing phase. Assuming no "breaks", the identity allows the data to be written in the following manner:

\[
X = \begin{bmatrix}
p & 0 & \ldots & \ldots & \ldots & \ldots & \ldots & 0 \\
p & 0 & \ldots & \ldots & \ldots & \ldots & \ldots & 0 \\
0 & p & 0 & \ldots & \ldots & \ldots & \ldots & 0 \\
q & p & 0 & \ldots & \ldots & \ldots & \ldots & 0 \\
\vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots \\
\vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots \\
0 & p & 0 & \ldots & \ldots & \ldots & \ldots & 0 \\
0 & 0 & p & 0 & \ldots & \ldots & \ldots & 0 \\
q & 1 & p & 0 & \ldots & \ldots & \ldots & 0 \\
0 & q & p & 0 & \ldots & \ldots & \ldots & 0 \\
\vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots \\
\vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots \\
0 & 0 & p & \ldots & \ldots & \ldots & \ldots & 0 \\
\vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots \\
0 & 0 & 0 & q & 1 & 1 & 1 & \ldots & 1 \\
\vdots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \vdots \\
\end{bmatrix}
\]

\[
B = \begin{bmatrix}
 b_1 \\
b_2 \\
\vdots \\
b_k \\
\end{bmatrix}
\]

\[
Y = \begin{bmatrix}
y_1 \\
y_2 \\
\vdots \\
y_n \\
\end{bmatrix}
\]

\[
E = \begin{bmatrix}
e_1 \\
e_2 \\
\vdots \\
e_n \\
\end{bmatrix}
\]

\( (n \times k) \)
Then
\[ XB = Y + E, \]
\[ (X'X)\hat{B} = X'Y, \]
\[ \hat{B} = (X'X)^{-1} X'Y, \]
the usual least squares solution. Separate estimates of \( B \) will be made for licensed and unlicensed hunters, and designated \( \hat{B}_2 \) and \( \hat{B}_1 \), respectively.

It would seem that if the time periods were fairly short, it would be permissible to simplify this somewhat by setting \( p = 1 \) and \( q = 0 \), which would result in a sizable saving of time in calculating the \( X'X \) and \( X'Y \) matrices. However, this would contribute considerable error, and also save less time, if time periods were several hours long. It is hard to say just what length of period would be short enough for this simplification, and it is likely that this will have to be determined by empirical methods. As the length of time defined for the sampling unit is yet to be determined, this point will not be considered further at present. It should be emphasized that the gain in computational time from defining \( q = 0 \) and \( p = 1 \) is restricted to the operation of developing the \( X'X \) and \( X'Y \) matrices, as inversion of the \( X'X \) matrix and subsequent operations will require the same machine time in either case.

It should also be emphasized that the least squares procedure still involves the assumption that there is no relationship between a person's success during a given hour and his presence -- hence probability of being contacted -- during any subsequent hour. It will be recognized that this assumption is not entirely realistic, as poor hunting may cause a person to stop and good hunting may allow him to fill the legal bag and stop. However, in applying these estimates in a ratio, it is not a bad assumption that both estimates are subject to the same relative bias due to the correlation between success and continuance of hunting, under which assumption the ratio is unbiased.
The preceding matrix procedure presents several difficulties. First, the variance under this definition has little meaning, as it is an arbitrary combination of within and among sampling unit variances. Rightfully, the true variation of our estimates depends on the among s.u. variance. Secondly, under this definition, there is no co-variance between the estimated kill by licensed hunters and the estimated kill by unlicensed hunters. This is unreasonable since the two are estimated from the same sampling units.

For these reasons, we consider another estimation procedure which involves summing the vectors in the preceding matrices over sampling units. Then each of our vectors will be of the form

\[
\sum_{k=1}^{r} y_{ijk} = b_j \left( \sum_{k=1}^{r} p_{ijk} \right) + b_{j-1} \left( \sum_{k=1}^{r} r_{ijk} \right) + \cdots + b_{j-z} \left( \sum_{k=1}^{r} r_{ijk} \right)
\]

where \( r_{ijk(j-t)} \) is the coefficient of the \( k^{th} \) hunter contacted for the \((j-t)^{th}\) time period, being either \( p, 1, q, \) or \( 0 \).

\( h_{ij} \) = number of licensed (or unlicensed as the case may be) hunters contacted in the \( i^{th} \) s.u. of the \( j^{th} \) time period.

and \( Y = BX - E \), as before in matrix notation.

Then in our matrices, we will have one vector for each sampling unit, and \( X_1 \), the \( X \) matrix for unlicensed hunters, will be of the same size as \( X_2 \), the \( X \) matrix for licensed hunters.

Then, as before,

\[
\hat{R}_{12} = \frac{\hat{Y}_1}{\hat{Y}_2} + 1 = \frac{\hat{Y}_1 + \hat{Y}_2}{\hat{Y}_2}
\]
where

\[ \hat{y}_1 = N_1 \hat{\hat{y}}_1, \]
\[ \hat{y}_2 = N_2 \hat{\hat{y}}_2, \]
\[ \hat{b}_1 = (x_1^i x_1) ^{-1} x_1^i y_1, \]
\[ \hat{b}_2 = (x_2^i x_2) ^{-1} x_2^i y_2, \]

and

\[ N_1 = \begin{bmatrix} h_{11} \\ h_{12} \\ \vdots \\ h_{1k} \end{bmatrix}, \quad N_2 = \begin{bmatrix} h_{21} \\ h_{22} \\ \vdots \\ h_{2k} \end{bmatrix}, \]

where

\[ h_{1j} = \text{the number of unlicensed hunters observed during the } j^{\text{th}} \text{ time period.} \]
\[ h_{2j} = \text{the number of licensed hunters observed during the } j^{\text{th}} \text{ time period.} \]

\[ V(\hat{R}_{12}) = (\hat{R}_{12})^2 \left\{ \frac{V(\hat{Y}_1 + \hat{Y}_2)}{(\hat{Y}_1 + \hat{Y}_2)^2} + \frac{V(\hat{Y}_2)}{\hat{Y}_2^2} - \frac{2 \text{ cov}(\hat{Y}_2, (\hat{Y}_1 + \hat{Y}_2))}{(\hat{Y}_2)(\hat{Y}_1 + \hat{Y}_2)} \right\} \]

\[ = (\hat{R}_{12})^2 \left\{ \frac{V(\hat{Y}_1) + V(\hat{Y}_2) + 2 \text{ cov}(\hat{Y}_1, \hat{Y}_2)}{(\hat{Y}_1 + \hat{Y}_2)^2} + \frac{V(\hat{Y}_2)}{(\hat{Y}_2)^2} - \frac{2[V(\hat{Y}_2) + \text{ cov}(\hat{Y}_1, \hat{Y}_2)]}{\hat{Y}_2(\hat{Y}_1 + \hat{Y}_2)} \right\} \]
\[
\left( \frac{\hat{Y}_1}{\hat{Y}_2} \right)^2 \left( \frac{V(\hat{Y}_1)}{\hat{Y}_1^2} + \frac{V(\hat{Y}_2)}{\hat{Y}_2^2} - \frac{2 \text{cov}(\hat{Y}_1, \hat{Y}_2)}{\hat{Y}_1 \hat{Y}_2} \right)
\]

where

\[
V(\hat{Y}_1) = [N_1 (X_1^\top X_1)^{-1} N_1] s_1^2
\]

\[
V(\hat{Y}_2) = [N_2 (X_2^\top X_2)^{-1} N_2] s_2^2
\]

\[
\text{cov}(\hat{Y}_1, \hat{Y}_2) = [N_1 (X_1^\top X_1)^{-1} (X_1^\top X_2)(X_2^\top X_2)^{-1} N_2] s_{12}
\]

and

\[
s_1^2 = \frac{Y_1^\top Y_1 - \hat{B}_1^\top X_1^\top Y_1}{n-k}
\]

\[
s_2^2 = \frac{Y_2^\top Y_2 - \hat{B}_2^\top X_2^\top Y_2}{n-k}
\]

\[
s_{12} = \frac{Y_1^\top Y_2 - Y_1^\top X_1 \hat{B}_2 - \hat{B}_1^\top X_1^\top Y_2 + \hat{B}_1^\top X_1^\top X_2 \hat{B}_2}{n-k}
\]

In the preceding treatment, \(N_1\) and \(N_2\) have been considered fixed quantities; that is, the estimates of variance are conditional on fixed \(N\). This is not realistic as the \(N\)'s are also random variates, but the effect of this cannot now be evaluated. A further consideration is that the variance of \(\hat{B}_1\) and \(\hat{B}_2\) estimated from the vectors summed over sampling units is probably somewhat greater than the variance of \(\hat{B}_1\) and \(\hat{B}_2\) estimated from the individual observation vectors. The importance of this also cannot be evaluated at present, but this point can be tested when field data are available.
In view of these considerations, an alternate method of computing the variance of $R_{12}$ is suggested. This is similar to the device used with the mail survey, and involves splitting the sample into a number of sub-samples, and computing the variance between the $R_i$'s estimated from each. There are any number of possible ways of splitting the sample, depending on the estimates of variance desired, and it will be possible to separate components of variance with an appropriate design. This phase should receive much further investigation.

Two additional ratios must be developed, one for the expansion of number of dove hunters and the other for the expansion of number of days hunted by dove hunters. Let us define:

**True population values,**

\[
\begin{align*}
H &= \text{Total number of hunters.} \\
\bar{d}' &= \text{Mean number of days hunted during the season.} \\
\bar{t}' &= \text{Mean number of hours hunted per day.}
\end{align*}
\]

**Sample values,**

\[
\begin{align*}
h &= \text{Observed number of hunters.} \\
\bar{d} &= \text{Mean number of days hunted prior to being contacted} \\
&\quad \text{(including day contacted).} \\
\bar{t} &= \text{Mean number of hours hunted on the day contacted prior to being contacted.}
\end{align*}
\]

The subscripts $u$ or $l$ will denote that these values are for unlicensed hunters or licensed hunters, respectively.
Now under random sampling, the probability of contacting any hunter is proportional to the length of time he is in the field, which relationship leads to the proportion,

\[
\frac{h_u}{h} = \frac{H \cdot d'' \cdot t''}{H \cdot d'' \cdot t''} = \frac{h_u}{h} \cdot \frac{d''}{d''} \cdot \frac{t''}{t''}
\]

Then we may define,

\[
R_2' = \frac{H \cdot d''}{H \cdot d''} \cdot \frac{h_u/\ell}{h/\ell} = \frac{h_u/\ell}{h/\ell}
\]

\[
R_3' = \frac{H}{H} \cdot \frac{h_u/\ell}{h/\ell} \cdot \frac{d''}{d''} = \frac{h_u/\ell}{h/\ell} \cdot \frac{d''}{d''}
\]

Now it will be noted that we have, not estimates of \(d''\) and \(t''\), but rather of \(d'\) and \(t'\), which represent unknown fractions of \(d''\) and \(t''\),

\[
d' = k_1 \cdot d''
\]

\[
t' = k_2 \cdot t''
\]

so that,

\[
R_2' = \frac{h_u/\ell \cdot (k_1 \cdot d'')}{h/\ell} = \frac{h_u \cdot k_2 \cdot (k_1 \cdot d'')}{h \cdot k_2 \cdot (k_1 \cdot d'')}
\]

\[
R_3' = \frac{h_u/\ell \cdot (k_1 \cdot d'') \cdot (k_2 \cdot d'')}{h/\ell \cdot (k_1 \cdot d'') \cdot (k_2 \cdot d'')} = \frac{h_u \cdot (k_1 \cdot k_2 \cdot d'') \cdot (k_1 \cdot k_2 \cdot d'')}{h \cdot (k_1 \cdot k_2 \cdot d'') \cdot (k_1 \cdot k_2 \cdot d'')}
\]
\[ V(\hat{R}_2) = V(\hat{R}_2') \]
\[ = (\hat{R}_2')^2 \left[ \frac{V(h_u)}{h_u^2} + \frac{V(h_\ell)}{h_\ell^2} + \frac{V(t_u)}{t_u^2} + \frac{V(t_\ell)}{t_\ell^2} \right. \]
\[ + \frac{l \text{ cov}(h_u, t_\ell)}{h_u t_\ell} + \frac{l \text{ cov}(h_\ell, t_u)}{h_\ell t_u} - \left( \frac{2 \text{ cov}(t_u, t_\ell)}{t_u t_\ell} \right. \]
\[ - \frac{l \text{ cov}(h_u, t_u)}{h_u t_u} - \frac{l \text{ cov}(h_\ell, t_\ell)}{h_\ell t_\ell} - \frac{8 \text{ cov}(h_u, h_\ell)}{h_u h_\ell} \]
\[ V(\hat{R}_3) = V(\hat{R}_3') \]
\[ = (\hat{R}_3')^2 \left[ \frac{9V(h_u)}{h_u^2} + \frac{9V(h_\ell)}{h_\ell^2} + \frac{V(t_u)}{t_u^2} + \frac{V(t_\ell)}{t_\ell^2} + \frac{V(d_u)}{d_u^2} + \frac{V(d_\ell)}{d_\ell^2} \right. \]
\[ + \frac{6 \text{ cov}(h_u, t_\ell)}{h_u t_\ell} + \frac{6 \text{ cov}(h_u, d_\ell)}{h_u d_\ell} + \frac{6 \text{ cov}(h_\ell, t_u)}{h_\ell t_u} + \frac{6 \text{ cov}(h_\ell, d_u)}{h_\ell d_u} \]
\[ + \frac{2 \text{ cov}(t_u, d_u)}{t_u d_u} + \frac{2 \text{ cov}(t_\ell, d_\ell)}{t_\ell d_\ell} - \frac{2 \text{ cov}(t_\ell, t_u)}{t_\ell t_u} - \frac{2 \text{ cov}(t_\ell, d_u)}{t_\ell d_u} \]
\[ - \frac{2 \text{ cov}(t_u, d_\ell)}{t_u d_\ell} - \frac{2 \text{ cov}(d_u, d_\ell)}{d_u d_\ell} - \frac{6 \text{ cov}(h_u, t_u)}{h_u t_u} - \frac{6 \text{ cov}(h_u, d_u)}{h_u d_u} \]
\[ - \frac{6 \text{ cov}(h_\ell, t_\ell)}{h_\ell t_\ell} - \frac{6 \text{ cov}(h_\ell, d_\ell)}{h_\ell d_\ell} - \frac{18 \text{ cov}(h_u, h_\ell)}{h_u h_\ell} \right]. \]
and if we may assume that \( k_{2u} = k_{2l} \) and \( k_{1u} = k_{1l} \), these formulae reduce to

\[
\begin{align*}
\hat{R}_2' &= \frac{h_t l l}{h_t^2 u}, \quad \hat{R}_2 = (\hat{R}_2' + 1), \\
\hat{R}_3' &= \frac{h_t d d}{h_t^3 u d_u}, \quad \hat{R}_3 = (\hat{R}_3' + 1).
\end{align*}
\]

As this seems to be a reasonable assumption, these formulae are recommended. However, further work should be done in this area, particularly in developing a test for validity of the assumptions made.

Approximate variances for \( \hat{R}_2 \) and \( \hat{R}_3 \) can be derived by use of Taylor's expansion. For purposes of expansion, let us redefine,

\[
\begin{align*}
\hat{R}_2 &= \frac{h_t l l}{h_t^2 u}, \quad \hat{R}_2' = \frac{h_t^2 l}{h_t^2 u}, \\
\hat{R}_3 &= \frac{h_t d d}{h_t^3 u d_u}, \quad \hat{R}_3' = \frac{h_t^3 d}{h_t^3 u d_u},
\end{align*}
\]

where
\[
\begin{align*}
h &= \text{observed number of hunters} \\
t &= \text{sum of hours hunted prior to being contacted} \\
d &= \text{sum of days hunted prior to being contacted, including day on which contacted.}
\end{align*}
\]

Note that it will make no difference if these values are taken to be means per sampling unit. In fact, that is the way computations should be made, but present notation will leave off bars for simplicity.
Design B.

The secondary phase of Design B is identical to that of Design A, with the exception that hunters are classified by whether or not they have a telephone listed in their name. It is suggested that the telephone number and exchange be recorded as part of the field data, as all records can then be checked if necessary.

It is in the primary phase that the two designs are different. It is not anticipated that there will be any real problem of non-response. If this does pose a problem, then data should be classified by some criterion of difficulty in collecting it, and these classes treated as returns in the estimation procedure used for Design A. Otherwise, the estimate of totals for the universe of telephone owners is,

\[ \hat{T} = \sum_{i=1}^{n} \frac{y_i}{n}, \]

where

- \( N \) = total number of residential telephones.
- \( y_i \) = the kill or days hunted or classification as a dove hunter (1 or 0) for the \( i^{th} \) individual in the sample.
- \( n \) = the number of individuals in the sample.

and this total is expanded to totals for the entire universe of dove hunters by the same formula used in Design A,

\[ \hat{T} = \hat{y}_T \hat{R}, \]

where \( R \) is estimated as in Design A.
and as before,

\[ v(\hat{y}) = \hat{\sigma}^2 v(\hat{y}_T) + \hat{\sigma}^2_T v(\hat{y}) , \]

where

\[
v(\hat{y}_T) = \frac{N^2}{n(n-1)} \left[ \sum_{i=1}^{n} y_i - \left( \frac{\sum_{i=1}^{n} y_i}{n} \right)^2 \right], \text{ if } y_i \text{ is kill or days,} \]

\[ = N^2 \frac{p(1-p)}{n-1}, \text{ if the item measured is dove hunters,} \]

\[
\sum_{i=1}^{n} y_i \]

and

\[
p = \frac{\sum_{i=1}^{n} y_i}{n}, \quad y_i = \begin{cases} 1 & \text{if the } i^{th} \text{ individual is a dove hunter.} \\ 0 & \text{if the } i^{th} \text{ individual is not a dove hunter.} \end{cases} \]

The foregoing formulae are dependent on the sampling design used, assuming simple random sampling and no fpc. The sampling design for Design B cannot be described at this time as it is dependent on the results of the frame tests. It may be necessary to change the given formulae to conform with the sampling design chosen. Because of the great potential importance of this design, it is strongly recommended that these tests be set up as soon as possible.

END OF REPORT
References:

The reader is referred to Schultz (47) for a very exhaustive list of references on this subject. The present list does not attempt to be exhaustive, but rather includes those references of special interest, those referred to directly in this report, and a few not included in Schultz's list. When a series of reports of results are available, such as the annual publication from West Virginia (48), a single type issue of the series has been listed, even though several authors may be involved over the years.


2. Anon. no date, no title, Utah State Dept. of Fish and Game, description of 1957 mail surveys with procedures and formulae.


21. ______ 1959. Prestige and memory bias in hunter kill surveys, Rhode Island Division of Fish and Game. Typed ms. 4 pp.


34. Hunter, G. N. no date. The random card method of obtaining information on small game resources. Colorado Game and Fish Dept. 10 pp.


42. no date. The economic value of the Minnesota sport fishery on the Mississippi River. Minn. Dept. Cons. 7 pp.


SUMMARY OF KILL SURVEY ACTIVITY IN THE VARIOUS STATES

Alaska

Previous year's kill of game and fur animals required in application for license. No indication given as to percentage of usable forms filled out.

Alabama

Negative

Arizona

1. Have used hunter report cards. These are reported unsatisfactory due to variable returns, low response level, unknown bias of non-response due to obvious correlation of hunter success and card return, and delay in return.

2. In addition to report cards, non-reporters were contacted on an approximate 5-year schedule. The extension of report data to all data was based on this 5-year questionnaire.

3. Are now using mail survey of sample of licensees. Percent response between 75 to 95, depending on species. Concerned about non-response error and plan interview followup of non-response.

4. One comparison of questionnaire, check station and hunter report card shows good agreement between percent hunter successes by the first two.

California

1. Mail survey of licenses used as the major source of information. Correspondent recognizes response errors, but does not mention non-response errors or level or response.

2. Test has been conducted by sending questionnaire to persons using co-op pheasant areas. Estimates from mail survey were roughly 2 1/2 times as great as check station records. Details of this study were not provided.
3. Mail survey estimates of deer kill are roughly twice the tagging system totals.

4. Comparison of mail survey to personal interview survey showed a close agreement for most species.

**Colorado**

1. Mail questionnaire begun 1948; systematic, every n\textsuperscript{th} license with every \( (n+1) \text{st} \) license as a possible alternate. Mailed in January based on list of license sales of previous year. Alternates mailed out if (a) first card returned by P.O.; (b) later discovered that licensee not licensed in actual year of survey. In 1948 (?) \( \frac{42.3}{4} \) response; this was broken down by counties.

2. Personal interview carried out in 1945-46 in Colorado started as a systematic sample of licenses, but later changed to a random sample. Cross checks made (a) against big game kill cards; (b) against kill of big game in first week and of 1 year olds (from kill cards); (c) against kill of big game by species and sex (d) duck stamp sales vs. waterfowl hunters; (e) pheasant kill checked against warden interview (very good agreement).

3. Colorado uses big game hunting report cards - to be filled out within 15 days after end of season. For 1948-53 average return was \( \frac{47.1}{4} \). Have checked this against check station blockades in two areas - error less than 0.1\% (not specified). However in 1949-50 the random surveys indicated kill to be 10\% higher than from report cards.

4. **Waterfowl:** survey by mail in 1956. Sent to 5000; 1571 usable waterfowl returns received. Hunters were notified directly before the season that they were part of sample. One follow-up.

**Connecticut**

Reports of game taken in previous year required at time of purchase of license, (seemingly discontinued in 1955). Report by Sondrini in 1950 of analysis of data from 1923-1944. Currently, collecting data only on permit areas.
Delaware

Mandatory check of all deer kill: no indication of efficiency. Also have reports of game taken in previous year at time of purchase of license.

Florida

Florida has conducted kill and hunting activity surveys since 1950, and prior to that time hunters were required to report the previous season's kill when purchasing a hunting license. For several years, beginning in 1950, mail surveys, hunter bag checks, and voluntary reports were used concurrently. The bag check was discontinued due to apathy on the part of Wildlife Officers, sampling problems in collection, and as the mail surveys were furnishing data of more reliance.

In the beginning, personal interviews of a sample of non-respondents were used to correct for bias of non-response, but the value of these interviews is open to question. Starting in 1954, regression techniques were used to correct this bias. These techniques were further refined in 1958. These data show a very definite decline in hunting activity with successive mail waves.

For five years, a parallel "Permanent Mailing List" was used in addition to the systematic sample of current licensees. This PML was composed of all respondents to the previous year's mail surveys, both PML and current. These data have not been thoroughly analyzed due to a lack of statistical theory in this area.

The voluntary reports of game killed were finally discontinued. Analysis showed a definite trend in mean kill on number reporting, but this varied greatly by area and by species, and no satisfactory corrections could be devised.

Georgia

Negative.
Idaho
1. First used mail survey to game bird hunters in 1953. Sample size approximately 9,000, with 7,000 response, including one follow-up. Sample size varies to 6,000; response to 4,000. Same questionnaire used for big game. Confidence limits provided for deer and elk by management units.
2. Discontinued follow-up mailing (which added 1½% to response) after two years as it did not significantly change estimates.

Illinois
Are using surveys (but did not say what). Have done no basic research in methodology.

Indiana
Uses standardized mail survey as reported by Barnes, 1946. Evidently one follow-up mailing, and cites evidence of bias of non-response.

Iowa
1. Creel census estimation of preserve and catch on several lakes.

Kansas
1. Mail survey to 5% of hunting license buyers.
2. Waterfowl kill survey based on USFWS methods.

Kentucky
1. Questionnaire conducted by Conservation Officer. Results are considered too high.
2. Consider determination of trends more important than total kill. Plan to expand their program.

**Louisiana**

Has used mail survey, but did not respond to our request for information.

**Maine**

1. Employs a mail survey to obtain information on resident game. Sample size around 10,000 with about 70-75% response after two reminders. Provide estimate of confidence limits, but unknown formula.

2. Also uses an expanded USFWS waterfowl sample to provide state estimate of waterfowl hunting preserve and kill. Service methods used.

**Maryland**

Mandatory checking of all deer and turkey. No estimate of small game kill since 1947 when law requiring return of small game kill report was repealed. A check (?) of these returns indicated that hunters either "exaggerated or minimized the kill for reasons best known to themselves".

**Massachusetts**

No methods of determining kill. Planning to start a postal card survey the coming year. (Random sample). Deer hunters required by law to report deer kill. Have worked with hunting pressure on public hunting grounds by personal contact on peak days.

**Michigan**

Michigan has done a good deal of work in several areas of kill and hunting pressure statistics. In particular, they have studied voluntary methods of reporting, and the bias involved, and have utilized and studied mail surveys, with checks by independent estimates from physical counts and compulsory
registration of kill. The details of these tests are too voluminous for the present treatment, but certain results will be summarized.

Mail surveys for small game have continued since 1954 and for deer since 1952. Response (to intensive follow-up) is 90-95% and non-delivery is negligible due to use of telephone directories for correcting addresses. An early survey for pheasant hunting (1953) utilized addresses from the previous year's licenses, which was considered undesirable. This survey had 8.6% undeliverable, indicating the effect of current administrative steps to eliminate this source of error. It was noted that rate of success decreased slightly with each mailing.

For more recent surveys, it is reported that there doesn't seem to be much change in kill per hunter with successive waves of small game response, but a definite decline in the deer kill surveys. It is also reported that comparisons of voluntary reports and mail survey results over the same years gave similar results for pheasants and rabbits, but widely different results for species hunted by fewer people, with the difference seeming to be a rather consistent function of proportion of licensees hunting the species.

Minnesota

1. Mail survey used to determine fishing expenditure and activities of non-resident anglers in 1956. 65% response to two waves.

2. Special study of effect of change of bag limit of ducks from 4 to 5 conducted in 1956 is very interesting. This study deviates from the usual kill survey in that it consists of diary data by party rather than only in total seasonal kill by individual.

3. A personal interview survey of fishermen in the area adjoining the Mississippi River, primarily to obtain economic data.

4. Personal interview, statewide survey of expenditure of resident fishermen in 1957.
5. Game kill statistics derived from hunter report cards, presumably of the mandatory type.

Missouri
1. Uses the Field Bag check for measuring kill of small game and waterfowl. (Reported by Crawford, 1951)
2. Measure deer kill by compulsory check station and by a return stub on the deer hunting permit.

Montana
Use mail surveys to obtain kill data on most species of big game and waterfowl. (Use USFWS method for waterfowl)

Nebraska
Use USFWS mail survey methods for estimation of waterfowl kill.

Nevada
1. Mail surveys used for estimation of big game and small game kill and hunting activity. Response in 1956 was, for example, 74% for residents and 92% for non-residents, in the case of big game questionnaires.
2. For big game, a return card questionnaire is attached to the tag. In 1956 response from this was 70%.

New Hampshire
Respondents from each year were used as a nucleus of mailing lists for the succeeding year, thus data after 1st year are questionable. Comparison can be made to information available from mandatory return of data from deer coupons. In 1947, the mail survey estimated 8,910 deer; estimate from coupons was 6,649.
2. Estimate of deer take from "coupons" cannot be here evaluated as the source of this information (Biennial Reports) has no mention of rate of response or methods of extension, if any.

3. 1953 Survey (mail and interview followup) of sportsman expenditure. Used "paired sample" method. Not real clear as to analysis due to conflicting statements. Report furnishes a good resume of administrative shortcomings.

New Jersey

Annual mail survey of small game kill. The mailing list is of necessity a year old when first used, and is used for two years, after which it is replaced by another one, again one year old. A single mailing is made, response errors being considered more important than non-response errors. Adaptation of Atwood's bias correction methods are used for all game. For one year old sample, 13%, and for two year old sample, 16-20% did not purchase a current license.

New Mexico

Postal contact with random sample of big game hunters. No specific information available. Mail survey of waterfowl and upland game bird harvest. Sample from year old list of licenses allowing a pre-season contact with wallet size tally card. Two mailings made after the season for 52% response. Of the respondents, 21% did not purchase a current license. Bias correction procedures are applied at least to the waterfowl data.

New York

1. Until 1956 collection of kill statistics was by license stub reports. Reasons given for discontinuing this are largely administrative, and no mention is made of bias due to incomplete response, or to other biases.

2. In 1957 a mail survey to current licenses was initiated. This is a systematic sample with random start, stratified by type of license. There was 76.3%
response to three waves. It was noted that some bias of non-response was present, but this was ignored as objectives are to measure trends rather than absolute levels.

North Carolina

1. Mail survey was conducted in 1949-50 (Stains and Barkalow), and from 1951-52 through 1954-55. This project was discontinued primarily because survey was not sufficiently sensitive to measure changes being observed.

   The sample was taken from the previous year's list of licenses. Two mailings resulted in 35 to 40 percent response. Non-respondents were subsampled (10%) and contacted by personal visitation. No mention is made of proportion of this subsample that could not be contacted.

2. Bag checks used for collecting biological data for doves and squirrels.

North Dakota

Conduct annual mail survey for upland game birds and waterfowl. Use procedures outlined by the Central Flyway, as developed by Atwood. (Do not report the source of addresses.)

Ohio

In past have used several means of collecting data:

1. Check stations on public hunting areas.
2. Aerial counts of hunters on study areas (pheasants).
3. Statewide hunter bag check by game protectors.
4. Questionnaire distributed to hunters contacted in the field on opening day of upland game season.

The first two have satisfactorily achieved their limited objectives; the last two have proven to be inadequate.

Currently initiating a sample survey of licenses. Intend to use bias correction procedures similar to Atwood's.
Estimates of waterfowl kill will be obtained from the USFWS by means of an expanded sample.

**Oklahoma**
1. All deer are checked through check stations.
2. Report cards are sent to Department from all deer hunters.
3. Check station records of kill and pressure for small game on public shooting areas.
4. Currently initiating a hunter kill survey based on Central flyway procedures, including all game species other than deer.

**Oregon**
1. Elk and deer tags were issued separate from the general license. A report card is issued with each tag, and the hunter is requested to submit a voluntary report of seasonal activity. In 1957, over 100,000 of 266,665 deer hunters submitted reports.
2. A random survey was conducted (year not specified) of 5,000 hunting license holders. A total of 4,961 questionnaires was received after repeated follow-ups. This is evidently an annual survey, and applies to deer and elk. Data on waterfowl and upland game kills were also obtained, but it was not stated how these data are related to the deer and elk tags.

**Pennsylvania**
No formal surveys have been used. The law requires that successful big game hunters report their kill. A card is furnished with each license for this purpose.

**Puerto Rico**
1. Questionnaire sent by mail to each (640) licensed hunter on the island.
2. Random bag checks provide data comparable to that from questionnaires.
Rhode Island

Having a small number of licensees (12,000), mail surveys have comprised 25%-100% of the total. A novel method of extension of results is used. Proportion of banded pheasants taken by the gun is established from public shooting areas, which are stocked at same rate as remainder of state. Reported banded pheasants killed is extended to this figure, and the extension factor used for all other items in the survey.

Response was 31% in 1955-56 season. This is presumably response to two mailings, although not so stated. Two mailings were made the following two years, but per cent response not reported.

South Carolina

Negative report.

South Dakota

Kill of upland game birds and waterfowl estimated by mail survey. Sample taken from previous years file of licensees, with unreported proportion of non-purchase of current license. No bias correction procedures used for state purposes, although corrected (as by Central Flyway procedures) waterfowl estimates are computed for comparative purposes. Two mail waves used.

Tennessee

Since 1953 kill data have been collected by means of a statewide hunter bag check collected by conservation officers. To supplement these data, a postal survey was conducted for three years of a sample of licensees. The previous year's list was used in 1954 and 1955. The 1956 sample was 1/2 the sample used the previous year. Rate of non-purchase of license was 5%, 8% and 13%, respectively. On all the three occasions two mailings were made, with response of 41, 38, and 27 per cent, respectively.
Texas

Reports were received of surveys conducted independently in two management regions.

A.

1. Post card questionnaire sent to each (6,611) licensee in the region (Trans Pecos).
2. Personal interviews made of a sample of 250 of above licensees who lived in the region.
3. Field bag checks made of hunter success of quail and dove. Results: Differences noted in results of post card and personal interview surveys. Mail survey data for small game were roughly adjusted for unlicensed kill by bag check data, using the ratio method.

B.

1. In 1953 and 1954 post card questionnaire delivered to one-third (selected by postman) of box holders, divided into strata; rural delivery, city delivery, post office box. Returns were 9.2% and 11.7% in the two years.
2. In 1955, data were collected by mail questionnaire to sample taken from car registration records.
3. Voluntary check stations are maintained around Region for purpose of collection of biological data. In conjunction, selected shooting preserve operators kept total records, from which the ratio of preserve killed to total checked deer was expanded to an estimate of total killed in the region.

Utah

1. Mail survey used (separately) for deer and game birds. Source of names is list of licensees of previous year. These surveys have continued since 1947.
Tests during first three years indicate for deer no bias of non-response. Sampling rate is 20% for deer and 10% for game birds. Some 42% response is received for deer hunters, presumably one mail wave.

2. Mail survey also used for statewide waterfowl kill, using Atwood's method.

3. Check station used to tally big game take on hunting units. Also used to tally sage grouse kill and waterfowl kill on refuges.

4. Bag check (periodic check station) used on waterfowl refuges.

5. Voluntary records of waterfowl kill submitted by hunt clubs.

**Virginia**

State law requires that all deer, bear, and turkey taken be checked at an official check station. No other methods are used in measuring kill.

**Washington**

1. Mail survey (90% response to unknown number of waves) covering both big and small game.

2. License report forms have been discontinued on basis of unreliability.

**West Virginia**

1. State law requires that all deer, bear, turkey and pheasant be reported within a specified time. Stations are set up for this purpose. It is the opinion of the Commission that these are accurate (complete?) to the following degree: bear, 100%; deer, 95%; turkey, 60%; pheasant, 30%.

2. Road blocks are set up in some areas to sample kill.

**Wisconsin**

1. State law requires direct registration of deer at department stations. This is a minimum estimate of total deer, but believed to include a very high per cent of the total.
2. Compulsory report of small game and waterfowl attached to license and due immediately after the season. Although the State estimates are not reliable, volume of data allows tabulation by county for which reason this phase is being continued.

3. Mail survey was conducted for three years (1950-52) on an experimental basis. In 1952, two mailings resulted in 74% response; in 1951, three mailings brought 87% response.

4. Mail survey was also used from 1944 to 1954 (?) to determine total deer kill. Response was reported to always be over 50%.

Wyoming

1. Use field checks by department personnel and check stations.

2. In 1956 initiated a questionnaire survey, which compares favorably with harvest information collected at check stations.