Sampling Methods for Production of Livestock Statistics-Part-I

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Sampling Methods for Production of Livestock Statistics

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Livestock Statistics- International Standards

- Terms "livestock" and "poultry" are used in a very broad sense, covering all domestic animals irrespective of their age and location or the purpose of their breeding
- Cattle, buffaloes, camels, sheep, goats, pigs, horses, mules, asses and chickens are raised and enumerated in many countries
- Some countries raise and enumerate ducks, geese, turkeys and beehives, whereas rabbits, guinea fowl, pigeons, silkworm cocoons, fur animals, reindeer and various kinds of came lids are limited to far fewer countries

Livestock Statistics- International Standards (Contd.)

- Livestock is generally classified by genera, subdivided in a few cases by species
- More frequently, individuals of various genera or families are being aggregated into a single group, e.g., "poultry" covers domestic fowls, guinea fowl, ducks, geese and turkeys
- FAO recommends that countries enumerate at least the animals listed below, classified according to the following list, taking into account national perspectives

Livestock Statistics- International Standards (Contd.)

List of Animals

- CATTLE, total
  - A. Calves and young stock under 1 year of age
  - B. Young stock, 1 year of age and under 2 years
  - C. Cattle, 2 years of age and over
  - a) Females: i) Cows - mainly for milk production; ii) Heifers (including in calf)
  - b) Males - mainly for meat production and for Work and Breeding, separately
- BUFFALOES, total
  - A. Buffaloes under 3 years of age
  - B. Buffaloes, 3 years of age and over Buffalo cows - mainly for milk production
- SHEEP, total
  - A. Lambs under 1 year of age
  - B. Sheep, 1 year of age and over Females - intended for breeding ; for products

Livestock Statistics- International Standards (Contd.)

List of Animals (Contd.)

- SLAUGHTER MALE GOATS, total
  - A. Goats under 1 year of age
  - B. Goats, 1 year of age and over - Females
- PIGS, total
  - A. Young pigs, less than 50 kg
  - B. Pigs for breeding, 50 kg and over - Gilts - gilts in pig - Sows - sows in pig
  - C. Pigs for fattening, 50 kg and over
    - a) 50 kg and less than 80
    - b) 80 kg and over

[Note: Above categories given under pigs for meat production is for exotic/ crossbred. An equivalent indigenous part is as follows. Body weights of adult indigenous pigs generally vary between 30 to 45 kg which are considered as young pigs, less than 50 kg.]

List of Animals (Contd.)

- HORSES, total
  - A. Horses for agricultural production or use
  - B. Other horses
- CAMELS total; MULES, total; ASSES, total
- CHICKENS (domestic fowl), total
  - A. Chickens for breeding and egg production - Laying hens and pullets
  - B. Chickens for meat production (slaughter) - Broilers - Other (capons, etc.)
  - C. Other chickens (multi-purpose mixed stock) - Laying hens and pullets
- TURKEYS, total ; DUCKS, total
- GEESE, total; GUINEA FOWL, total; RABBITS, total;
- BEEHIVES, total

Livestock Statistics- International Standards (Contd.)

Livestock Products

- Livestock products from slaughtered animals
  - **Primary products:** Products, coming directly from slaughtered animals, including meat, offals, raw fats, fresh hides and skins
  - **Processed products:** Derived from processing of primary products and include sausages, lard and salted hides
- **Definition of meat:** Flesh of animals used for food, with bone-in, unless otherwise stated, excludes meat unfit for human consumption, edible offals & slaughtered fats
- **Concept of meat production:** Data on meat production are usually reported according to one or more of the following concepts:
  - **Live weight of animals intended for slaughter:** Weight taken immediately before slaughter

Livestock Statistics- International Standards (Contd.)

Livestock Products (Contd.)

- Concept of meat production (Contd.)
  - **Killed weight:** Gross weight of the carcass including hide/ skin, head, feet & internal organs, but excluding part of blood not collected in the course of slaughter.
  - **Dressed carcass weight:** Weight of the carcass after removal of the certain parts
- Production of meat for minor animals (poultry, rabbits, game, etc.):

Usually reported according to one or the other of the following concepts:

a = Thighs + Wings+ Breast + Ribs + Back = Ready-to-cook (oven ready)

b = a + Heart + Liver + Gizzard + Neck = Ready-to-cook (incl. giblets)

c = b + Feet + Head = Eviscerated weight

d = c + Viscera (inedible offals) = Dressed weight

e = d + Blood + Feathers + Skins (when applicable) = Live weight

Livestock Statistics- International Standards (Contd.)
Livestock Products (Contd.)

Concept of meat production changes with the coverage of production as :

- **Production from slaughtered animals (SP):** All animals of indigenous and foreign origin, slaughtered within the national boundaries.
- **Production from indigenous animals (GIP):** Indigenous animals slaughtered plus the exported live animals of indigenous origin.
- **Total indigenous production (TIP) :** Indigenous animals slaughtered + exported live animals + net additions to stock during reference period
- **Primary products:** Includes milk, eggs and fibers of animal origin
- **Processed products:** Products derived from primary products

Livestock Statistics- International Standards (Contd.)

Livestock Products from Live Animals

- **Milking animals and milk production**
  - Milking animals include all females in reproductive age/ Only dairy females bred especially which were actually milked during the year
  - Gross production of Milk includes milk actually milked and milk sucked by young animals
  - Net production of Milk excludes milk sucked by young animals but includes amounts of milk fed to livestock
  - FAO concept relates to Net milk production as above, and Milking animals to all animals which have contributed to produce that milk
  - Data on production delivered to dairies are easily obtained from the dairy plants

Livestock Statistics- International Standards (Contd.)-

Layers and egg production statistics of hatcheries

- Layers: All females in laying age, whether laying or not/ Only those females of egg-type breeds which have laid eggs during the year
- Female layers are classified by breed according to dominant production characteristics: Egg-type females, Meat-type, and Mixed-type.
- Layers also classified according to agricultural sector where they are bred: Traditional sector (widely scattered and individually-owned small flocks in farms and backyards), Modern sector (large scale, semi-intensive and intensive commercial poultry farms)
- FAO concept of Egg production covers all domestic female birds which have contributed to the egg production during the year, wherever they lay and the corresponding total production, including eggs intended to be used for hatching but excluding waste on farms

Livestock Statistics- International Standards (Contd.)-

Layers and egg production statistics of hatcheries

- In line with FAO concept, countries may report at least annually on layer numbers and egg production.Layers of all types (egg-type, meat-type, mixed-type females) and from all (traditional , semi-intensive , intensive) sectors which have laid eggs during the year should be included
- In all cases, separate data be collected and released by countries according to various kinds of domestic birds: hens, ducks, goose, turkeys, etc.
- Hatcheries data on number of eggs placed in incubators, chicks hatched and chicks placed, separately for chickens, ducks, geese, turkeys and guinea fowl
- Figures for chickens should be divided into, at least, two categories: Eggs/chicks for laying stock and Eggs/chicks for meat stock

Wool and Fine Hair production statistics

- Wool production data should be collected and released by all countries, including both shearing wool and pulled wool (recovered from skins)
- Wool production figures should be reported on both a greasy basis and a clean or scoured basis. When reported in one way only, appropriate conversion factors should be included
- Countries producing significant quantities of fine hair or wool, such as cashmere and mohair, should report relevant production figures separate from common wool figures

SAMPLING METHODS FOR ESTIMATION OF PRODUCTION FOR MAJOR LIVESTOCK PRODUCTS

- In past the only source of livestock statistics in countries was quinquennial livestock census (LSC)
- LSC started in 1919, latest being 2012
- LSC provides statistics on age-wise, sex-wise, breed-wise (crossbred and nondescript) number of animals at one point of time
- LSC conducted normally after every five years. Intercensal estimates are not available from this source
- Official estimates of production were those obtained by using livestock numbers projections for the year and norms of yield per animal obtained from studies and/or market surveys

SAMPLING METHODS FOR ESTIMATION OF PRODUCTION FOR MAJOR LIVESTOCK PRODUCTS (Contd.)

- Studies and market surveys were not based on objective criteria and as such had limited utility
- Objectively planned Sample Surveys provide an answer to such problems
- Indian experience of conducting Integrated Sample Survey (ISS) for estimation of major livestock products viz. milk, eggs, wool and meat will be discussed in the present module
- The ISS has been evolved using knowledge acquired from series of methodological studies on individual basis and also pilot surveys (conducted by IASRI) with the concept of integrated approach for simultaneous estimation of all these products in a single survey
- Estimates are worked out on seasonal basis

Sampling Design and sample size covered under Integrated Sample Surveys

- The sampling design being adopted for the ISS for the estimation of production of milk, eggs, wool and meat is a **stratified multi-stage random sampling** with
  - Villages as the **first stage unit**
  - Households / cluster of households as the **second stage unit** and
  - Animals within the households as the third and **ultimate stage unit** whereas no sub-sampling of layers within a household is done for recording data on egg production
- The animal husbandry districts in the states are taken as **strata**
- A State is considered as a population for surveys

Sampling Design and sample size covered under Integrated Sample Surveys (Contd.)

- For estimation of livestock numbers a sample of 15% of villages are selected in the state for complete enumeration of livestock population (5 % villages in each season, viz. rainy, winter and summer)
- Samples of villages in each season are allocated to different strata in proportion to the population of livestock in them. From the selected villages a representative sample of 10-12 villages are selected for collection of detailed information for the estimation of district level estimates of milk, eggs, wool and meat
- Sample of villages is allocated to different tehsils/sub-districts which constitutes a sub-strata according to livestock population in them

Sampling Design and sample size covered under Integrated Sample Surveys (Contd.)

- The selection of **second stage units** is done with equal probability and without replacement with sample size as follows:
- *1st Round*
  - Milk: 2 clusters of 2 households each
  - Eggs: 2 clusters of 5 households each
  - Wool: Sample of 5 households (Flocks)
  - Meat: 2 recognized slaughter houses
- *2nd, 3rd and 4th Rounds*
  - Milk: 4 clusters of 2 households each
  - Eggs: 4 clusters of 5 households each
  - Wool: Sample of 8 households (Flocks)
  - Meat: 2 recognized slaughter houses

Sampling Design and sample size covered under Integrated Sample Surveys (Contd.)

- Recording of wool yield is done in shearing season in selected villages from the sample of 5/8 households having sheeps
- Selection of **ultimate unit** of sampling is done with equal probability and without replacement and the sample covered as follows.
  - Milk: Two animals in milk (one cow and one buffalo or both cows or both buffaloes as the case may be) and all goats in milk
  - Eggs: All the laying birds
  - Wool: Two rams / two whether, two ewes, two lambs
  - Meat: Three sheep, three goats, three pigs

Sampling Design and sample size covered under Integrated Sample Surveys (Contd.)

- For estimation of meat production, an additional sample of two registered slaughter houses are selected at random in each stratum in a round and
- Information on meat production are collected from the sample of three animals of each species viz. sheep, goats, pigs and buffaloes.

Estimation of Milk Production

- Estimates of number of animals in milk / milch animals, average milk yield per day per animal in milk / per milch animal and total milk production and their estimates of variances are discussed
- Procedure, in the first instance, is discussed for one season and for one category of animals, say, cows.
- Methods of pooling the estimates over different seasons are mentioned subsequently
- Procedure in the case of buffaloes is similar to that for cows

Estimation of milk production (Contd.)

Notations:

Let V = total number of villages in the State

n' = total number of villages selected during the year which is 15 per cent of total number of villages in the State, n' = 0.15 × V

n = n' / 3 = number of villages selected in a season

T = number of strata formed in the State.

V_h = total number of villages in the h^{th} stratum

n_h = number of villages allocated to the h^{th} stratum for complete enumeration of livestock numbers.

Thus $$n = \sum_{h=1}^{T} n_h$$

Estimation of milk production (Contd.)

Notations (Contd.):

v_h = a sub-sample of villages selected from the n_h villages in the h^{th} stratum for yield estimation

M_{srhi} = number of animals in milk as enumerated in the i^{th} village of the h^{th} stratum during the r^{th} round of the s^{th} season. It may be noted here that the changes in the number of animals within a season are not substantial and may be ignored

Thus, $M_{srhi} = M_{shi}$ for r = 1,2,3,4

u_{srhi} = number of households in the sample from i^{th} village in the h^{th} stratum during the r^{th} round of the s^{th} season

Estimation of milk production - Notations(Contd.)

m_{srhij} = number of animals in milk for which a day's yield is recorded from the j^{th} household in the i^{th} village of the h^{th} stratum during the r^{th} round of the s^{th} season

y_{srhijk} = milk yield of the k^{th} animal in the j^{th} household of the i^{th} sample village in the h^{th} stratum during the r^{th} round of the s^{th} season

M'_{hi} = number of animals in milk in the i^{th} village of the h^{th} stratum according to the latest Live Stock Census (LSC)

$$M'_h = \sum_{i=1}^{V_h} M'_{hi} \quad , \quad M' = \sum_{h=1}^{T} M'_h$$

Similarly, let N_{shi} , N'_{hi} , N'_h and N' be the corresponding notation for the number of milch (in milk + dry) animals

Estimation of milk production - (Contd.)

Estimates of number of animals in milk/ milch and their estimates of variances in a season is given by

$$\hat{M}_S = \sum_{h=1}^{T} \hat{M}_{sh} \quad \text{, Where} \quad \hat{M}_{sh} = \hat{R}_{sh} \times M'_h \quad , \qquad \hat{R}_{sh} = \frac{\sum_{i=1}^{n_h} M_{shi}}{\sum_{i=1}^{n_h} M'_{hi}}$$

Similarly, estimate of number of milch animals in a season is given by

$$\hat{N}_S = \sum_{h=1}^{T} \hat{N}_{sh} \quad \text{, Where } \hat{N}_{sh} = \hat{R}'_{sh} \times N'_h \qquad \hat{R}'_{sh} = \frac{\sum_{i=1}^{n_h} N_{shi}}{\sum_{i=1}^{n_h} N'_{hi}}$$

Estimate of variance of $\hat{M}_S$ is given by

$$Est.V(\hat{M}_S) = \sum_{h=1}^{T} Est.V(\hat{M}_{sh})$$

Estimation of milk production - (Contd.)

Estimates of number of animals in milk/ milch and their estimates of variances in a season is given by (Contd.)

where approximately

$$Est.V(\hat{M}_{sh}) = \frac{V_h^2 \sum_{i=1}^{n_h} (M_{shi} - \hat{R}_{sh} M'_{hi})^2}{n_n (n_n - 1)}$$

Similarly, estimates of variance of $\hat{N}_S$ is given by

$$Est.V(\hat{N}_S) = \sum_{h=1}^{T} Est.V(\hat{N}_{sh})$$

Where, approximately

$$Est.V(\hat{N}_{sh}) = \frac{V_h^2 \sum_{i=1}^{n_h} (N_{shi} - \hat{R}'_{sh} N'_{hi})^2}{n_n (n_n - 1)}$$

Estimation of milk production - (Contd.)

Estimate of average milk yield per animal in milk/ milch per day and total milk production and their estimates of variance

Estimate of average milk yield per animal in milk per day is given by

$$\bar{y}_{sh} = \frac{\sum_{i=1}^{V_h} M_{shi}\bar{y}_{shi}}{\sum_{i=1}^{V_h} M_{shi}}, \quad \bar{y}_{shi} = \frac{1}{d_s}\sum_{r=1}^{d_s}\bar{y}_{srhi} \quad \text{and} \quad \bar{y}_{srhi} = \frac{\sum_{j=1}^{u_{srhi}}\sum_{k=1}^{m_{srhij}} y_{srhijk}}{\sum_{i=1}^{V_h} M_{shi}}$$

where d_s = number of rounds (months) in the s^{th} season.

Similarly, estimate of average milk yield per milch animal per day is given by

$$\bar{Z}_{sh} = \frac{\sum_{i=1}^{V_h} M_{shi}\bar{y}_{shi}}{\sum_{i=1}^{V_h} N_{shi}}$$

Estimation of milk production - (Contd.)

Estimate of average milk yield per animal in milk/ milch per day and total milk production and their estimates of variance (Contd.)

Estimate of variance of $\bar{y}_{sh}$ is given by

$$Est.V(\bar{y}_{sh}) = \frac{1}{V_h(V_h - 1)} \sum_{i=1}^{V_h} \frac{M_{shi}^2}{\hat{M}_{sh}^2} (\bar{y}_{shi} - \bar{y}_{sh})^2$$

where $\hat{M}_{sh} = \dfrac{\sum_{i=1}^{V_h} M_{shi}}{V_h}$

Similarly, Est. V (Z_{sh}) can be worked out exactly in a similar manner

Estimation of milk production - (Contd.)

Estimate of total milk production and its estimate of variance

Estimate of total milk production per day in the h^{th} stratum and in the s^{th} season is given by

$$\hat{P}_{sh} = \hat{M}_{sh} \times \bar{y}_{sh}$$

Estimate of the variance of P_{sh} is given by

$$Est.V(P_{sh}) = \hat{M}_{sh}^2 \; Est.V(\bar{y}_{sh}) + \bar{y}_{sh}^2 \; Est.V(\hat{M}_{sh})$$

where Est. V($\bar{y}_{sh}$) and Est. V($\hat{M}_{sh}$) are already defined.

Estimate of total milk production per day in a season over all the strata is given by $\hat{P}_s = \sum_{h=1}^{T} \hat{P}_{sh}$

and estimated variance $Est.V(\hat{P}_s) = \sum_{h=1}^{T} Est.V(\hat{P}_{sh})$

Estimation of milk production - (Contd.)

Estimate of total milk production and its estimate of variance(Contd.)

An estimate of average milk yield per animal in milk per day pooled over all the strata is given by

$$\bar{y}_s = \frac{\hat{P}_s}{\hat{M}_s} = \frac{\sum_{h=1}^{T} \hat{P}_{sh}}{\sum_{h=1}^{T} \hat{M}_{sh}}$$

Estimate of the variance of $\bar{y}_s$ is given by

$$Est.V(\bar{y}_s) = \frac{1}{\hat{M}_s^2}[Est.V(\hat{P}_s) + \bar{y}_s^2 Est.V(\hat{M}_s) - 2\bar{y}_s Cov.(\hat{P}_s, \hat{M}_s)] \text{ ,}$$

where

$$Est.Cov.(\hat{P}_s, \hat{M}_s) = \sum_{h=1}^{T} Est.Cov.(\hat{P}_{sh}, \hat{M}_{sh})$$

Estimation of milk production - (Contd.)

Estimate of total milk production and its estimate of variance(Contd.)

Further

$$Est.Cov.(\hat{P}_{sh}, \hat{M}_{sh}) = \frac{V_h^2 \sum_{i=1}^{V_h} (M_{shi}\bar{y}_{shi} - \hat{R}''_{sh}M'_{hi})(M_{shi} - \hat{R}_{sh}\hat{M}'_{hi})}{V_h(V_h - 1)}$$

$$\hat{R}''_{sh} = \frac{\sum_{i=1}^{V_h} M_{shi}\bar{y}_{shi}}{\sum_{i=1}^{V_h} M'_{hi}}$$

Estimation of milk production - (Contd.)

Pooling of the estimates and the estimates of their variances over the different seasons

Let M, N, y, z and P be the estimates of animals in milk, milch animals, average milk yield per day per animal in milk / per milch animal and total milk production per day in the entire year.

Then,

$$\hat{M} = \sum_{S=1}^{3} Q_S \hat{M}_S$$

Q_s is the relative period of the season viz. $\frac{d_s}{12}$ and $\sum_{S=1}^{3} Q_S = 1$

Similarly, $\hat{N} = \sum_{S=1}^{3} Q_S \hat{N}_S$ and $\hat{P} = \sum_{S=1}^{3} Q_S P_S$

$Est.V(\hat{M}) = \sum_{S=1}^{3} Q_S^2 Est.V(\hat{M}_S)$; $\bar{y} = \frac{\sum_{S=1}^{3} \hat{M}_S \bar{y}_S}{\hat{M}}$; $\bar{y} = \frac{\hat{P}}{\hat{M}}$ approximately

Estimation of milk production - (Contd.)

Pooling of the estimates and the estimates of their variances over the different seasons(Contd.)

$$Est.V(\hat{N}) = \sum_{S=1}^{3} Q_S^2 Est.V(\hat{N}_S) \; ; \quad \overline{Z} = \frac{\sum_{S=1}^{3} \hat{N}_S \overline{Z}_S}{\hat{N}} \; ; \quad \overline{Z} = \frac{\hat{P}}{\hat{N}}$$ approximately

$$Est.V(\hat{P}) = \sum_{S=1}^{3} Q_S^2 Est.V(\hat{P}_S) \; ; \; Est.Cov.(\hat{P}, \hat{M}) = \sum_{S=1}^{3} Q_S^2 Est.Cov.(\hat{P}_S, \hat{M}_S)$$

Est.V($\overline{y}$) may be taken as approximately equal to:

$$Est.V(\overline{y}) = \frac{1}{\hat{M}^2}[Est.V(\hat{P}) + \overline{y}^2 Est.V(\hat{M}) - 2\overline{y} Est.Cov.(\hat{P}, \hat{M})$$

Similarly,

$$Est.V(\overline{Z}) = \frac{1}{\hat{N}^2}[Est.V(\hat{P}) + \overline{Z}^2 Est.V(\hat{N}) - 2\overline{Z} Est.Cov.(\hat{P}, \hat{N})$$

Estimation of Egg Production

- Estimates of number of layers (adult female birds), average egg production per layer and total egg production and estimates of variances of these estimates are discussed
- Procedure, in the first instance, is discussed for one season and with reference to one species and breed of poultry birds
- Procedure for other species and breeds will be identical
- Methods of pooling the estimates and estimates of their variances over different seasons are also discussed

Estimation of Egg Production (Contd.)

Notations: Similar to Milk production estimation, Let,

V = total number of villages in the Population (State)

n' = total number of villages in sample selected during the year which is 15% of total number of villages, i.e., n' = 0.15 × V

n = n' / 3 = number of villages selected in a season

T = number of strata formed in the Population (State)

V_h = total number of villages in the h^{th} stratum

n_h = number of sampled villages allocated to the h^{th} stratum for complete enumeration of livestock numbers

Thus $$n = \sum_{h=1}^{T} n_h$$

Estimation of Egg Production- Notation (Contd.)

v_h : a sub-sample of villages selected from the n_h villages in the h^{th} stratum for yield estimation

M_{s1hij} : number of layers (of the breed and species under consideration) in the j^{th} household of i^{th} village of h^{th} stratum during the 1^{st} round of the s^{th} season

U_{srhi} : number of households in the sample (observed for recording egg production) from the i^{th} village in the h^{th} stratum during r^{th} round of the s^{th} season

m_{srhij} : number of layers on the day of visit in the j^{th} household of i^{th} village of h^{th} stratum during r^{th} round of s^{th} season

Estimation of Egg Production- Notation (Contd.)

y_{srhij} : number of eggs laid by m_{srhij} birds described above

M'_{hi} : be the number of layers in the i^{th} village of the h^{th} stratum according to the latest Live Stock Census (LSC) data

$$M'_h = \sum_{i=1}^{v_h} M'_{hi} \qquad \text{and} \qquad M' = \sum_{h=1}^{T} M'_h$$

Estimation of Egg Production (Contd.)

Estimate of number of layers and estimate of its variance

Estimate of Number of Layers in a season is given by

$$\hat{M}_S = \sum_{h=1}^{T} \hat{M}_{sh} \qquad \text{where} \qquad \hat{M}_{sh} = \frac{\sum_{i=1}^{n_h} M_{s1hi}}{\sum_{i=1}^{n_h} M'_{hi}} \times M'_h$$

Estimate of variance of $\hat{M}_{sh}$ may be approximately taken as,

$$Est.V(\hat{M}_{sh}) = \frac{V_h^2 \sum_{i=1}^{n_h} (M_{s1hi} - \hat{R}_{sh} M'_{hi})^2}{n_n (n_n - 1)} \qquad \text{where} \qquad \hat{R}_{sh} = \frac{\sum_{i=1}^{n_h} M_{s1hi}}{\sum_{i=1}^{n_h} M'_{hi}}$$

$$Est.V(\hat{M}_S) = \sum_{h=1}^{T} Est.V(\hat{M}_{sh})$$

Estimation of Egg Production (Contd.)

Estimates of average egg production per layer per day and total egg production and estimates of their variances

Estimate of average egg production per layer per day in the hth stratum during the sth season is given by

$$\bar{y}_{sh} = \frac{\sum_{i=1}^{v_h} M_{s1hi}\bar{y}_{shi}}{\sum_{i=1}^{v_h} M_{shi}}$$, where $$\bar{y}_{shi} = \frac{1}{d_s}\sum_{r=1}^{d_s}\bar{y}_{srhi}$$ and $$\bar{y}_{shi} = \frac{1}{d_s}\sum_{r=1}^{d_s}\bar{y}_{srhi}$$

d_s being the number of rounds in the sth season

Estimate of variance of $\bar{y}_{sh}$ is given approximately by

$$Est.V(\bar{y}_{sh}) = \frac{1}{v_h(v_h-1)}\sum_{i=1}^{V_h}\frac{M_{slhi}^2}{\hat{\bar{M}}_{sh}^2}(\bar{y}_{shi}-\bar{y}_{sh})^2$$ where $$\hat{\bar{M}}_{sh} = \frac{\sum_{i=1}^{v_h} M_{slhi}}{v_h}$$

Estimation of Egg Production (Contd.)

Estimates of average egg production per layer per day and total egg production and estimates of their variances (Contd.)

Estimate of total egg production per day in the h^{th} stratum and in the s^{th} season is given by $\hat{P}_{sh} = \hat{M}_{sh} \times \bar{y}_{sh}$

Estimate of variance of $\hat{P}_{sh}$ is $Est.V(P_{sh}) = \hat{M}_{sh}^2 \; Est.V(\bar{y}_{sh}) + \bar{y}_{sh}^2 \; Est.V(\hat{M}_{sh})$

An estimate of total egg production per day in a season for the entire population is given by

$$\hat{P}_s = \sum_{h=1}^{T} \hat{P}_{sh}$$,and estimated variance $$Est.V(\hat{P}_s) = \sum_{h=1}^{T} Est.V(\hat{P}_{sh})$$

An estimate of average egg production per layer per day pooled over all the strata is given by

$$\bar{y}_s = \frac{\hat{P}_s}{\hat{M}_s} = \frac{\sum_{h=1}^{T} \hat{P}_{sh}}{\sum_{h=1}^{T} \hat{M}_{sh}}$$

Estimation of Egg Production (Contd.)

Estimates of average egg production per layer per day and total egg production and estimates of their variances (Contd.)

Estimate of the variance of $\bar{y}_s$ is given by

$$Est.V(\bar{y}_s) = \frac{1}{\hat{M}_s^2}[Est.V(\hat{P}_s) + \bar{y}_s^2 Est.V(\hat{M}_s) - 2\bar{y}_s Cov.(\hat{P}_s, \hat{M}_s)]$$

where,

$$Est.Cov.(\hat{P}_s, \hat{M}_s) = \sum_{h=1}^{T} Est.Cov.(\hat{P}_{sh}, \hat{M}_{sh})$$

where,

$$Est.Cov.(\hat{P}_{sh}, \hat{M}_{sh}) = \frac{V_h^2 \sum_{i=1}^{V_h} (M_{slhi}\bar{y}_{shi} - \hat{R}'_{sh}M'_{hi})(M_{slhi} - \hat{R}_{sh}\hat{M}'_{hi})}{v_h(v_h - 1)}$$

Where, $\hat{R}'_{sh} = \frac{\sum_{i=1}^{v_h} M_{slhi}\bar{y}_{shi}}{\sum_{i=1}^{v_h} M'_{hi}}$

Estimation of Egg Production (Contd.)

Pooling of the estimates and the estimates of their variances over different seasons

Let $\hat{M}$, $\bar{y}$ *and* $\hat{P}$ be the estimates of number of layers, average egg production per layer per day and total egg production per day in the season, then

$$\hat{M} = \sum_{S=1}^{3} Q_S \hat{M}_S$$

where Q_s is the relative period of the season, viz $\frac{d_s}{12}$ and $\sum_{S=1}^{3} Q_S = 1$

$$\bar{y} = \frac{\sum_{S=1}^{3} \hat{M}_S \bar{y}_S}{\hat{M}} \quad , \quad \hat{P} = \sum_{S=1}^{3} Q_S P_S \quad , \quad \bar{y} = \frac{\hat{P}}{\hat{M}}$$ approximately

Estimation of Egg Production (Contd.)

Pooling of the estimates and the estimates of their variances over different seasons (Contd.)

$$\bar{y} = \frac{\sum_{S=1}^{3} \hat{M}_S \bar{y}_S}{\hat{M}} \quad , \quad \hat{P} = \sum_{S=1}^{3} Q_S P_S \quad , \quad \bar{y} = \frac{\hat{P}}{\hat{M}}$$ approximately

$$Est.V(\hat{P}) = \sum_{S=1}^{3} Q_S^2 Est.V(\hat{P}_S) \qquad Est.V(\hat{M}) = \sum_{S=1}^{3} Q_S^2 Est.V(\hat{M}_S)$$

Est.V ($\bar{y}$) may be taken as approximately equal to:

$$Est.V(\bar{y}) = \frac{1}{\hat{M}^2}[Est.V(\hat{P}) + \bar{y}^2 Est.V(\hat{M}) - 2\bar{y} Est.Cov.(\hat{P}, \hat{M})]$$

Where $Est.Cov.(\hat{P}, \hat{M}) = \sum_{S=1}^{3} Q_S^2 Est.Cov.(\hat{P}_S, \hat{M}_S)$

THANKS