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ESTIMATION OF INLAND FISHERY RESOURCES AND FISH CATCH

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SUMMARY

A pilot sample survey to evolve a suitable sampling methodology for estimation of inland fishery resources and total catch of fish from them was undertaken in 24-Parganas district of West Bengal jointly by the Indian Agricultural Statistics Research Institute, New Delhi and Central Inland Fisheries Research Institute, Barrackpore. Alternative estimators tried for estimation of area under ponds and tanks and fish catch from them are presented in this paper. The efficiencies of these estimators have also been compared in obtaining more precise estimates.

Keywords : Two stage cluster sampling, Consistent estimator, Ratio estimator, Efficiency.

1. Introduction

Ponds and tanks constitute an important source of inland fisheries in the States of Eastern and North-Eastern regions and in the plains of medium and high rainfall in Central and Southern India. Fishing and allied activities in ponds and tanks also provide a supplemental source of income for a large number of rural families. Accurate statistics are, however, not available in the village records about the area under ponds and tanks. The position regarding estimates of catch is still worse. Although, in most parts of the country, bulk harvesting from ponds and tanks is done during the period March to June, yet small catches con-

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tinue to be taken all through the year by fishermen for personal consumption. Therefore, recording of total catch of fish from a pond and building up reliable estimates of production has been a major problem which has so far defied all attempts for solution [1, 2, 3]. It was in this context that a study was undertaken by the IASRI, New Delhi jointly with CIFRI, Barrackpore in 24-Parganas district of West Bengal with a view to evolve a sampling methodology for estimation of area under ponds and tanks and of catch of fish from them.

2. The Sampling Design

The sampling design followed in the survey consisted of two stage cluster sampling, clusters of villages and ponds within villages constituted the first and second stage units respectively. A sample of 10 clusters of 4 villages each was selected from the district. The ponds and tanks in each of the selected villages were completely enumerated for estimating the area under them.

For estimating the total catch of fish 10 ponds were selected at random from each of the ten clusters. Each of these 100 ponds was visited 8 times in a month by the field staff for collection of data on fish catch. If catch was done on these dates, it was recorded species-wise by weight as well as their numbers. For the intervening period between two successive days of recording through physical observation, the data on fish catch were collected through enquiry. Therefore, both the methods of physical observation as well as enquiry were followed for recording data on fish catch.

3. Estimation Procedure

For estimation of area under ponds and fish catch from them different estimators were used which are given as below.

3.1 *Estimation of Area*

3.1.1 *Estimation of average area on per water unit basis*

Let N be the number of clusters consisting of 4 villages each in the district. Let M_{ij} be the number of ponds in the jth village of the ith cluster and let a_{ijk} be the area of the kth pond in the (i, j)th village. We wish to estimate the average area of a water unit in the district defined by

$$\bar{A} = \frac{\sum_{i=1}^{N} \sum_{j=1}^{4} \sum_{k=1}^{M_{ij}} a_{ijk}}{\sum_{i=1}^{N} \sum_{j=1}^{4} M_{ij}}$$

on the basis of a sample of n clusters of 4 villages each. The data on area under ponds as per revenue records was available for all 4 villages only in 4 clusters and for 2 villages in another 2 clusters. Similarly, the data on maximum area during monsoon and minimum during summer was available for all 4 villages only in 9 out of 10 clusters and for 3 villages in the remaining cluster. The data on pond area was recorded for all the 10 clusters of villages on the date of visit. Therefore, in the following estimators we take different values for estimates as per revenue records, at the time of visit, maximum in monsoon and minimum in summer.

Estimator I : *Mean of cluster means*

We define $$\bar{a}'_n = \frac{1}{n} \sum_{i=1}^{n} \bar{a}_i$$

where $$\bar{a}_i = \frac{1}{v_i} \sum_{j=1}^{v_i} \bar{a}_{ij}$$

and $$\bar{a}_{ij} = \frac{1}{M_{ij}} \sum_{k=1}^{M_{ij}} a_{ijk}$$

v_i stands for the number of villages in the ith cluster. Obviously, $\bar{a}'_n$ is a biased estimator, bias being low only when correlation between M_{ij} and $\bar{a}_{ij}$ is small and the sample size is sufficiently large. Neglecting, the bias term, variance of $\bar{a}'_n$ is given by

$$V(\bar{a}'_n) = \left(\frac{1}{n} - \frac{1}{N} \right) S_b'^2$$

where $$S_b'^2 = \frac{1}{N-1} \sum_{i=1}^{N} (\bar{a}_i - \bar{A}_N)^2$$

An unbiased estimator of $V(\bar{a}_n)$ is approximated for large N as,

$$\text{Est} \cdot V(\bar{a}_n') = \frac{s_b'^2}{n}$$

where $$s_b'^2 = \frac{1}{n-1} \sum_{i=1}^{n} (\bar{a}_i - \bar{a}_n')^2$$

3.1.2 *Estimation of average area under water units on per village basis*

Estimator based on cluster means :

We define $$M_e = \frac{1}{n} \sum_{i=1}^{n} \bar{a}_i$$

where $$\bar{a}_i = \frac{1}{4} \sum_{j=1}^{4} a_{ij}$$

a_{ij} being the total area under water units in the jth village of the ith cluster ($i = 1, 2, \ldots, 10$).

An unbiased estimate of $V(M_e)$ may be obtained as

$$\hat{V}(M_e) = \frac{1}{n(n-1)} \sum_{i=1}^{n} (\bar{a}_i - M_e)^2$$

Estimator II; Weighted mean of ctuster means

We consider the following estimator of $\bar{A}$

$$\bar{a}_n'' = \frac{\sum_{i=1}^{n} \sum_{j=1}^{v} M_{ij} \bar{a}_{ij}}{\sum_{i=1}^{n} \sum_{j=1}^{v} M_{ij}}$$

This is a ratio estimator. It is also biased but is a consistent estimator. Variance of $\bar{a}_n''$ is given by

$$V(\bar{a}_n'') = \left(\frac{1}{n} - \frac{1}{N} \right) S_b''^2$$

where $$S_b''^2 = \frac{1}{(N-1)^v} \sum_{i=1}^{N} \sum_{j=1}^{v} \frac{M_{ij}^2}{\bar{M}^2} (\bar{a}_{ij} - \bar{a})^2$$

$$\text{Est. } V(\bar{a}_n^u) = \frac{1}{n} s_b^{u2}$$

where $$s_b^{u2} = \frac{1}{(n-1)v} \sum_{i=1}^{n} \sum_{j=1}^{v} \frac{M_{ij}^2}{\bar{M}_n} (\bar{a}_{ij} - \bar{a}_n^u)^2$$

$$\bar{M} = \frac{1}{Nv} \sum_{i=1}^{N} \sum_{j=1}^{v} M_{ij}$$

and $$\bar{M}_n = \frac{1}{n} \sum_{i=1}^{n} \sum_{j=1}^{v} M_{ij}$$

3.2 *Estimation of Fish Catch*

Let

N = the total number of clusters in the population

M_i = the total number of ponds in the ith cluster ($i = 1, 2, \ldots, 10$)

y_{ij} = the fish catch during the year for the jth selected pond in the ith cluster ($j = 1, 2, \ldots, 10$)

a_{ij} = the water area (in bighas) of the jth selected pond in the ith cluster

n = the total number of ponds in the sample, i.e. 100

$\bar{M} = \frac{1}{N} \sum_{i=1}^{N} M_i$ is the average number of ponds in a cluster

3.2.1 *Estimate of fish catch per pond per year*

I. *Estimator based on cluster means*

Estimate of the fish catch per pond per year is given by

$$\bar{y}_p = \frac{1}{10} \sum_{i=1}^{10} \frac{1}{10} \sum_{j=1}^{10} y_{ij}$$

The estimate of variance is given by

$$\text{Est.}\,[\text{MSE}\,(\bar{y}_p)] = \left(\frac{1}{10} - \frac{1}{N}\right) s_b^2 + \frac{1}{10N} \sum_{i=1}^{10} \left(\frac{1}{10} - \frac{1}{M_i}\right) s_i^2$$

where $$s_b^2 = \frac{1}{9} \sum_{i=1}^{10} (\bar{y}_i - \bar{y}_p)^2$$

$$s_i^2 = \frac{1}{9} \sum_{j=1}^{10} (y_{ij} - \bar{y}_{i.})^2$$

and $$\bar{y}_{i.} = \frac{1}{10} \sum_{j=1}^{10} y_{ij}$$

II. *Ratio estimator for fish catch per pond per year*

Using number of ponds in a cluster as an auxiliary variate the ratio estimator for fish catch per pond per year is given by

$$\bar{y}_{rp} = \frac{\sum_{i=1}^{10} M_i \bar{y}_{i.}}{\sum_{i=1}^{10} M_i}$$

where $$\bar{y}_{i.} = \frac{1}{10} \sum_{j=1}^{10} y_{ij}$$

The estimate of variance is given by

$$\text{Est.}\,[V(\bar{y}_{rp})] = \left(\frac{1}{10} - \frac{1}{N}\right) \frac{1}{9} \sum_{i=1}^{10} u_i^2 (\bar{y}_{i.} - \bar{y}_{rp})^2 + \frac{1}{10N} \sum_{i=1}^{10} u_i^2 \left(\frac{1}{10} - \frac{1}{M_i}\right) s_{iy}^2$$

where $u_i = \frac{M_i}{\bar{M}}$ and $s_{iy}^2 = \frac{1}{9} \sum_{j=1}^{10} (y_{ij} - \bar{y}_{i.})^2$

3.2.2 *Estimate of fish catch per hectare per year*

I. *Estimator based on cluster means*

Estimate of fish catch per hectare per year is given by

$$\bar{y}_a = \frac{1}{10} \sum_{i=1}^{10} \frac{1}{10} \sum_{j=1}^{10} \frac{y_{ij}}{a_{ij}} \times 7.4$$

where 7.4 is the factor used for converting per bigha catch into per hectare.

The estimate of variance is given by

$$\text{Est. [MSE } (\bar{y}_a)] = \left(\frac{1}{10} - \frac{1}{N}\right) s_b^2 + \frac{1}{10N} \sum_{i=1}^{10} \left(\frac{1}{10} - \frac{1}{M_i}\right) s_i^2$$

where $$s_b^2 = \frac{1}{9} \sum_{i=1}^{10} (\bar{y}_i' - \bar{y}_a)^2$$

$$s_i^2 = \frac{1}{9} \sum_{j=1}^{10} \left(\frac{y_{ij}}{a_{ij}} \times 7.4 - \bar{y}_i'\right)^2$$

and $$\bar{y}_i' = \frac{1}{10} \sum_{j=1}^{10} \frac{y_{ij}}{a_{ij}} \times 7.4$$

II. *Ratio estimator for fish catch per hectare per year*

The estimate for fish catch per hectare per year is given by

$$\bar{y}_a' = \frac{\bar{y}_p}{\bar{a}_p} \times 7.4$$

where $$\bar{a}_p = \frac{1}{10} \sum_{i=1}^{10} \frac{1}{10} \sum_{j=1}^{10} a_{ij}$$

The estimate of variance is given by

$$\text{Est. } [V(\bar{y}_a')] = \frac{1}{\bar{x}_n^2}\left[\hat{V}(\bar{y}_p) + \bar{y}_a'^2\,\hat{V}(\bar{a}_p) - 2\bar{y}_a'\,\widehat{\text{Cov}}.\,(\bar{y}_p, \bar{a}_p)\right]$$

where $$\hat{V}(\bar{y}_p) = \left(\frac{1}{10} - \frac{1}{N}\right) s^2_{b(y)} + \frac{1}{10N}\sum_{i=1}^{10}\left(\frac{1}{10} - \frac{1}{M_i}\right) s^2_{i(y)}$$

$$\hat{V}(\bar{a}_p) = \left(\frac{1}{10} - \frac{1}{N}\right)\frac{s^2_{b(a)}}{(7.4)^2} + \frac{1}{10N}\sum_{i=1}^{10}\left(\frac{1}{10} - \frac{1}{M_i}\right)\frac{s^2_{i(a)}}{(7.4)^2}$$

$$\widehat{\text{Cov}}\cdot(\bar{y}_p, \bar{a}_p) = \left(\frac{1}{10} - \frac{1}{N}\right)\frac{s_{b(a,\,y)}}{7.4} + \frac{1}{10N}\sum_{i=1}^{10}\left(\frac{1}{10} - \frac{1}{M_i}\right)\cdot\frac{s_{i(a,\,y)}}{7.4}$$

4. Results and Discussions

4.1 *Average Area of Water Units*

As shown in Sections 3.1.1 and 3.1.2 of the estimation procedure, two different estimators of the average area of water units have been worked out. These estimators alongwith their percent standard errors are given in Table 1.

TABLE 1—ESTIMATES OF THE AVERAGE AREA PER WATER UNIT OF PONDS (in ha)

Estimator	*As per revenue records*	*At the time of visit*	*Max. in monsoon*	*Min. in summer*
I $\bar{a}_n'$	0.1321	0.1049	0.1211	0.0789
% S. E. $(\bar{a}_n')$	27.25	18.11	14.86	13.94
II $\bar{a}_n''$	0.1404	0.0903	0.0961	0.0617
% S. E. $(\bar{a}_n'')$	27.77	14.44	14.73	13.20

It would be seen that estimator—I is based on mean of cluster means while estimator II is a ratio estimator which takes into account the variation in number of ponds from cluster to cluster. As would be expected, estimator II is more precise than estimator I except in case of revenue records although the gain is only marginal. The estimators obtained from revenue records are based on much smaller number of observations and hence may not be relied upon.

4.2 *Average Area under Water Units on per Village Basis*

From the estimates of average area per water unit as defined in Section 4.1, one can arrive at the average area under water units on per village basis by multiplying the estimated area under a water unit with the estimated number of water units per village.

There could yet be another approach to arrive at the average area under water units per village. This approach is based on village as a unit and takes into account the total area of all the water units in a village. For the sampling design adopted in the survey one such estimator has been obtained and designated as M_c. The estimator M_c alongwith its standard error is given in Table 2.

TABLE 2—AVERAGE AREA UNDER WATER UNITS PER VILLAGE (in ha)

Estimator	*As per revenue records*	*At the lime of visit*	*Max. in monsoon*	*Min. in summer*
M_c	3.70	3.79	4.28	2.75
% S. E. (M_c)	18.92	18.33	17.52	18.92

4.3 *Estimates of Fish Catch per Pond per Year*

The catch of fish was estimated both on the basis of per pond as well as per hectare. Ratio method of estimation was also tried to improve the precision of estimators with number of ponds as the auxiliary variate. It was seen that in case of cluster sampling the fish catch per pond per year was estimated to be 246.014 kg with 25.53 per cent standard error whereas in case of ratio estimator, the fish catch per pond per year was obtained as 200.314 kg with 21.17 per cent standard error (Table 3).

TABLE 3—ESTIMATE OF FISH CATCH (in kg per pond per year)

S. No.	*Estimator*	*Estimate* $(\hat{\bar{y}})$	% *S. E.*
1.	Ratio estimate	200.314	21.17
2.	Cluster sampling	246.014	25.53

Similarly, the fish catch when estimated on per hectare basis was worked out to be 1360 kg per year using cluster sampling with 16.16 per cent standard error (Table 4).

TABLE 4—ESTIMATE OF FISH CATCH (in kg per hectare per year)

Estimator	*Estimate*	% *S. E.*
Cluster sampling $(\bar{y}_a)$	1360	16.16
Cluster sampling $(\bar{y}'_a)$	1125	15.85

4.4 *Efficiency of Cluster Sampling*

If the ponds were selected using simple random sampling without replacement, assuming that the finite population correction can be ignored, the estimate of per cent standard error comes to 20.53. The estimated relative efficiency of two stage cluster sampling with respect to simple random sampling without replacement is 0.6467 or the loss in efficiency due to two stage cluster sampling is 35 percent.

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