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ICAR- Central Inland Fisheries Research Institute

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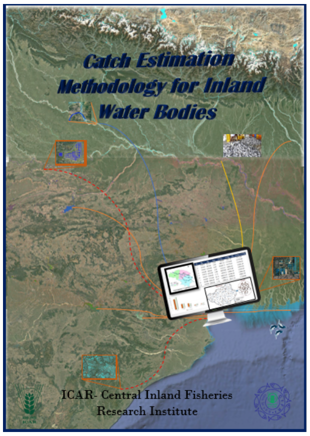


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# Table of Contents

# 1 Overview of Inland Fish Catch Estimation in India

## 1.1 Introduction

Inland fisheries concern activities to harvesting fish from '*inland waters*'. The terminology 'inland waters' mainly refers to freshwater systems; many areas are, however, classified as 'inland waters' which have daily or seasonal fluctuations in salinity—for example, estuaries, deltas, coastal lagoons, and creeks; some areas are permanently brackish water (coastal lagoons) or even hypersaline (creek). Besides marine waters, India is endowed with all types of water bodies mentioned above. Thereby, to distinguish between marine and 'inland waters' in the Indian context, 'inland waters' includes lakes, floodplain wetlands, rivers, estuaries, reservoirs, streams, ponds, irrigation tanks, canals, coastal lagoons, creeks, brackish water lagoons, and other land-locked waters—usually freshwaters. In India, fisheries in 'inland waters' comprise mainly two kinds: capture and culture. Capture fisheries refer to harvesting fish from open waters like rivers, estuaries, wetlands, creeks, and lagoons. The culture fisheries refer to harvesting fishes that are grown under confinement. In addition, there exist mixed fisheries consisting of both capture and culture. For instance, there are reservoirs wherein a portion is used for cage culture, and the rest is left for capture fisheries. A similar kind of mixed fisheries also exists in some wetlands in India.

## 1.2 Significance of inland fisheries in India

Since long fish is an important source of food for human, providing an important source of nutrition, food security as well as micronutrients. These nutritional and food security benefits are an integral part of a country's growth.

# 2 Some Basic Concepts in Statistical Surveys

A statistical survey broadly refers to collecting data to fulfil a definite need which arises in every conceivable sphere of human activities—including fisheries. India has a strong foundation in statistical surveys or censuses concerning human population, labour, economy, industry, agriculture and livestock. However, statistical fishery surveys are not as rich as in the sectors mentioned above.

The fishery is the channel between the harvested fish and the marketplace. It reacts sensitively to stimuli from both sides; to change in conditions of supply in the source, and to change in conditions of demand in the market. This dynamic behaviour is a barrier to the direct implementation of the statistical surveys that are followed in the typical areas mentioned above. Keeping track of the channel is somewhat easy for marine fisheries but highly difficult for inland fisheries. Because, as described in Chapter 1, the fisheries associated with 'inland waters' are highly dispersed. Therefore, typical statistical concepts used in other surveys should be redefined in the context of inland fisheries.

## 2.1 Basic Statistical Concepts

### 2.1.1 Population of units

An aggregate collection of clearly defined objects is called 'population of units'. It sometimes refers by only population. We will interchangeably refer it either as the 'population of units' or, simply, the population. A few examples are:

1. A population of students in a classroom, each student is a 'population unit';

2. A population of fishermen involved in a reservoir, a river stretches or a floodplain wetland: a fisherman who is involved in the fisheries associated with the water bodies is a 'population unit', and collection of all fishermen from the 'population of units' or simply 'population';
3. A population of active fishermen in a reservoir, river stretch or floodplain wetland: here the only an active fisherman is a 'population unit'. As because, all fishermen do not involve in fishing activities, though they are categorized as a fisherman.
4. A 'population unit' can be an aquaculture pond in a district. In such case, all the listed aquaculture ponds in a district constitute a population.

In statistical survey the definition of a 'population units' depends on the objectives of the study. Typically, it involves three basic features:

1. The definition of the unit of the population;
2. The span of geographical area of the population—for examples, a whole river from origin to sea mouth, a river stretch, a district, state, block and tehsil etc.
3. The fixing of limits other than geographical area—for example, excluding waterbodies where fishing activities is absent.

### 2.1.2 Population characteristics

Every population unit carries several characteristics. For examples, in a human population, an individual carries a great number of characteristics, such as,

- sex
- age
- weight
- income
- religion and many more

Similar characteristics can be thought of for a fish population. In the inland fisheries context, suppose we define a 'population of units' or population of reservoirs in a district, then population characteristics may include following:

- The area at full reservoir level (FRL)
- The minimum area
- Annual or monthly fish harvest

infeasible in statistical surveys to compute fish production from 'inland waters'. This document focuses, therefore, on the statistical sample survey. The following figure (Fig. 2.1) illustrates the concept of a population and a sample. In this illustration, the geographical area of the population is a district of a state and water bodies within the district are the population units. A sample (shown in different colour) is the water bodies selected by a suitable sampling technique for estimating area or fish catch.

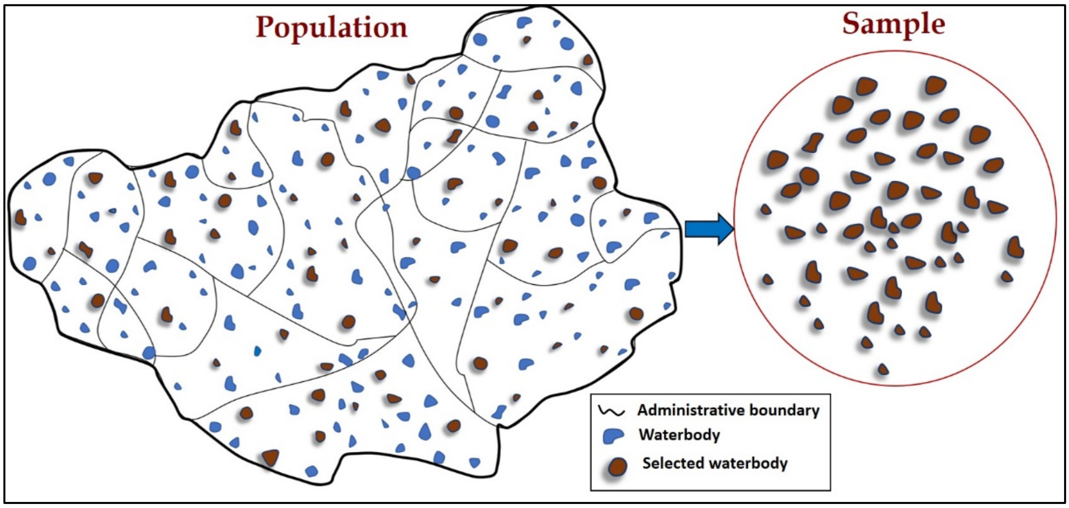



Fig. 2.1 A pictorial presentation of a population and a sample

### 2.1.4 Frame survey

A frame survey is a kind of inventory survey. In such survey, information is collected on a number of basic characteristics needed to assess the size and structure of inland fisheries. This survey also targets a predetermined geographical span—for example, a district—of the 'population of units'. Usually, the following items of information are covered by the frame survey:

Type of fisheries—capture, culture and culture-based;

1. Total number of landing sites, if exist;
2. Whether fishery is commercial or artisanal or recreational;
3. Type of 'inland waters'—floodplain wetland, lakes, reservoir, estuaries, rivers stretch;
4. The number of aquaculture ponds or tanks and total area under aquaculture;

5. Total water area exploited for fisheries associated with floodplain wetland, lakes, and reservoirs;
6. Total number of floodplain wetlands, reservoirs, lakes;
7. The total number of fishermen involved in fisheries associated to a particular resource;
8. Fishing crafts and gear.

The results of a frame survey are usually used to set up the 'Sampling Frame' of the population under study. The well-established sampling frame is very useful for the selection of samples of various surveys covering the population. By definition, a 'Sampling Frame' is the complete list of units from which samples are drawn. The examples are:

- the complete list of aquaculture ponds;
- the complete list of reservoirs;
- the complete list of fishermen of a water resource;
- the complete list of landing sites; and
- the complete list of fish disposal markets.

In practice, it is almost impossible and very difficult to get the full list mentioned above. However, in the later chapter, we describe the construction of sampling frame for each resource type that do not necessarily require such a complete list. The sampling frame must adequately reflect the population image, there is no statistical theory or concept to determine an ideal sampling frame. It demands the judgment of experts in inland fisheries being studied.

### 2.1.5 Coverage error

During the field operation of the frame survey, the coverage errors might occur, for examples:

- ***Omission of landing sites:*** It happens quite often in inland fisheries. This type of error affect both the total number of existing landing sites in the area under study and the total number of fishing units (fishing boats, fishermen, fishing gear, etc.). In case of aquaculture, omission of ponds or tank is highly probable.
- ***Counting errors:*** It occurs due to incomplete coverage of fishing unit within landing sites of rivers, reservoirs, floodplain wetlands, which might include fishermen, the fishing days, active fishermen etc.

# 3 Catch estimation procedure for pond and tanks

In Indian scenarios, ponds are usually earthen, shallow and excavated water bodies, though masonry dykes are also included (Gupta et. al. 1991). Whereas tanks are shallow water bodies—usually larger than a pond created by constructing earthen or masonry barricades—that receive water either from tube wells or rain (Gupta et. al. 1991); water retention is generally seasonal in these water bodies, as they get dried during summer due to the shallow water level. Large community ponds, small irrigation impoundments, temple tanks and natural tanks fed by the catchment from neighbouring areas also fall under this category. The average area of these types of waterbodies, in general, is below 10 ha. Generally, poly carp is practised in these water bodies with the utilisation of low to moderate levels of inputs, especially organic-based fertilisers and feed.

The foremost step for the statistical catch assessment survey of these water bodies is to set the threshold limits the area of water bodies for which the statistical survey is planned for. From past experience, this document sets the area of below 10 ha, assuming a similar kind of fishery exists. In India, these water bodies are exploited primarily for commercial or rural aquaculture. This chapter practically describes the methodology for estimating fish catch for aquaculture—both commercial and rural aquaculture. For water bodies of below 10 ha where capture fisheries exist, it is better to exclude those water bodies to implement the method described in this chapter, as the aim is the estimation of aquaculture (commercial or rural) fish production. Additionally, it is recommended to include water bodies more than 10 ha , if they are exploited for commercial or rural aquaculture.

## 3.1 Sampling frame

In this case, the population's geographical area is a district of a state. The survey objective is the estimation of a district-level fish catch. The 'population unit' is an individual water body. So the complete list of water bodies constitutes the sampling frame from which the sampling scheme is to be devised. For a more precise estimate, the population can be sub divided into more than one sub population. For instance, the water bodies can be divided into three sub-population, depending upon the culture practices—intensive, semi-intensive and low-intensive fish culture. To minimize the coverage error, exclusion of unharvested water bodies is strongly recommended. Once the population (either single or sub-population) is fixed, the sampling scheme is determined. Fish catch data should ideally be collected from a sub-sample of the basic units available in the district to obtain the district-level catch estimate. However, the entire study area, i.e., the district, is spatially very large and difficult to cover the entire part. More specifically, it is very difficult to determine the sampling frame—by enlisting all water bodies in the district. Thereby, the sampling frame is restructured for a two-stage sampling procedure, which enables the selection of the samples in two stages—aiming to reduce the sample size as well as survey efforts and cost. First, all basic units (ponds/tanks) of the study area are grouped into clusters, and the complete list of clusters constitutes the sampling frame for the first stage. The list of water bodies within a cluster then constitutes the sampling frame for the second stage sampling. The second stage of sampling involves selecting ponds/tanks from sampled clusters which finally constitute the sample units to be surveyed for catch estimation. The two-stage sampling is well proven and recommended sampling design for this type of estimate. The details of the steps are described below.

## 3.2 Two stage sampling

As mentioned above, the entire population is divided into clusters (group of water bodies). Then a sample of clusters is randomly selected. After cluster selection (First-stage sampling), new samples (study units) are randomly chosen from each selected cluster. The clusters are the first-stage units, called primary or first sampling units. The second-stage units are the elements of those clusters, called sub-units, secondary or second sampling units. Two stages of sampling consist of

- First-stage samples with $n$ primary units
- Second-stage, for the $i^{th}$primary unit, selects $m_i$(not all) secondary units

### 3.2.4 Case 1: The harvested area known

In this case, one can straightforwardly obtain the fish catch estimation from the equation (3.1). The proposed catch estimation procedure does not involve the total water spread area; only waterbodies which are used and harvested for fish culture are considered for catch estimation. However, it is useful for knowing the total water area of the district as well as the area of waterbodies which are not used for fish culture. Fishery departments may pay attention to the non-harvested water bodies which can be transformed to fish culture for more production. It is strongly recommended to conduct a separate survey—once in 3 to 5 years— to record the total water spread area and the total harvested area of the district.

### 3.2.5 Case 2: The average harvested area and number of harvested waterbodies known

The scenario presented in **Case 1** essentially require complete enumeration of water bodies in the district, which incur high cost. But, it is easier to know the total number of water bodies and the average area of those water bodies, typically based on prior experience. If average harvested area and number of total harvested waterbodies in the district are known, then total harvested area can easily be calculated by multiplying the average harvested area by the number of waterbodies in the district. The resultant total harvested area can then be used in the equation (3.1) to obtain the total catch of the district.

### 3.2.6 Case 3: Nothing known

When a practitioner fails to gather information on the harvested area, the alternative approach is to estimate the total harvested area that is require to obtain the catch estimate using the equation (3.6). The estimation of harvest area based on sampling methodology is described below; though it is highly discouraged due to propagation of errors in the catch estimate.

***Estimation of the total water spread area in the district:***

For estimation of water spread area, devise the sampling design to collect sample data as discussed before.

Let's assume,
$N$ —the total number of clusters in the district;
$M$ —the total number of waterbodies in the district;

Table 3.11: Variance and covariance calculation of water bodies of first cluster

| Cl | W. body | Pond area (ha) | Catch (Kg) | | | $s_{ica}$ | $s_{ia}^2$ | $s_{ic}^2$ |
|---|---|---|---|---|---|---|---|---|
| | | $a_{ij}$ | $c_{ij}$ | $a_{ij}-\bar{a}_i$ | $c_{ij}-\bar{c}_i$ | $(c_{ij}-\bar{c}_i)(a_{ij}-\bar{a}_i)$ | $(a_{ij}-\bar{a}_i)^2$ | $(c_{ij}-\bar{c}_i)^2$ |
| 1 | 1 | 0.20 | 160 | 0.088 | 19.00 | 1.672 | 0.00774 | 361.0 |
| 1 | 2 | 0.20 | 115 | 0.088 | -26.00 | -2.288 | 0.00774 | 676.0 |
| 1 | 3 | 0.01 | 125 | -0.102 | -16.00 | 1.632 | 0.01040 | 256.0 |
| 1 | 4 | 0.05 | 135 | -0.062 | -6.00 | 0.372 | 0.00384 | 36.0 |
| 1 | 5 | 0.10 | 170 | -0.012 | 29.00 | -0.348 | 0.00014 | 841.0 |
| **Total** | | **0.56** | **705** | | | **1.040** | **0.02988** | **2170.0** |
| **Mean** | | **0.11** | **141** | **Total/$(m_i-1)$** | | **0.260** | **0.00747** | **542.50** |

Table 3.12: Variance calculation of second- stage sampling- part1

| Cl. | $s_{ia}^2$ | $s_{ic}^2$ | $s_{ica}$ | $2Rs_{ica}$ | $R^2s_{ia}^2$ | $s_{ic}^2-2Rs_{ica}+R^2s_{ia}^2$ |
|---|---|---|---|---|---|---|
| 1 | 0.0075 | 542.50 | 0.26 | 436.66 | 5267.44 | 5373.28 |
| 2 | 0.0245 | 405.00 | 2.91 | 4887.23 | 17276.09 | 12793.86 |
| 3 | 0.0445 | 2120.00 | 6.05 | 10160.73 | 31379.02 | 23338.29 |
| 4 | 0.0238 | 400.00 | 3.05 | 5122.35 | 16803.64 | 12081.29 |
| 5 | 0.0372 | 4332.00 | 3.96 | 6650.66 | 26252.60 | 23933.94 |
| 6 | 0.0213 | 2230.00 | 2.75 | 4618.52 | 14984.36 | 12595.85 |
| 7 | 0.0349 | 7270.00 | 10.75 | 18054.20 | 24588.46 | 13804.26 |
| 8 | 0.0568 | 4628.30 | 8.27 | 13889.13 | 40066.42 | 30805.59 |
| 9 | 0.0258 | 2080.00 | 1.78 | 2989.44 | 18157.52 | 17248.08 |

Table 3.13: Variance calculation of second- stage sampling- part2

| Cl. | $M_i'$ | $\frac{1}{m_i}-\frac{1}{M_i'}$ | $\left(\frac{M_i'}{M'}\right)^2$ | $\left(\frac{M_i'}{M'}\right)^2\left(\frac{1}{m_i}-\frac{1}{M_i'}\right)\left(s_{ic}^2-2Rs_{ica}+R^2s_{ia}^2\right)$ |
|---|---|---|---|---|
| 1 | 20 | 0.15 | 0.629 | 506.786 |
| 2 | 22 | 0.15 | 0.761 | 1504.307 |
| 3 | 21 | 0.15 | 0.693 | 2465.310 |
| 4 | 33 | 0.17 | 1.712 | 3509.526 |
| 5 | 29 | 0.17 | 1.322 | 5237.051 |
| 6 | 24 | 0.16 | 0.905 | 1805.741 |
| 7 | 22 | 0.15 | 0.761 | 1623.111 |
| 8 | 31 | 0.17 | 1.511 | 7805.987 |

# 4 Catch estimation methods for artisanal fishing

The characteristics that exactly qualify as "artisanal fishing" vary, especially over countries. However, the Food and Agriculture Organisation defines it as:

> *"Traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption. In practice, definition varies between countries, e.g. from gleaning or a one-man canoe in poor developing countries, to more than 20-m. trawlers, seiners, or long-liners in developed ones. Artisanal fisheries can be subsistence or commercial fisheries, providing for local consumption or export. They are sometimes referred to as small-scale fisheries."* (FAO, 2015)

In what follows from the definition, artisanal fisheries entail location-specific traditional fishing by individual households or individuals, and the fishing techniques are essentially traditional involving minimal technological investment. There is no clear cut definition of artisanal fisheries in India. In whatever way, Indian inland capture fisheries are mostly small-scale—especially in streams, rivers, wetlands etc. Individuals primarily fish in those water bodies in many Indian states; thereby, artisanal fishing exists in those water resources. Specifically, artisanal fishing prevails in all the Hilly states for subsistence. The state government usually issues a license to an individual for fishing. Harvests through individual fishing are mostly used for household consumption, and thereby, those catches or harvests are unaccounted for state-level catch estimates. This section recommends two simple catch estimation procedures for artisanal fishing.

## 4.1 Population structure and sampling frame

The first step is to identify the water resources where artisanal fishing prevails. A rapid survey in the district will be helpful in recognizing it. The catch or harvest from the water resources, e.g. rivers, is the characteristic of the population. The objective is to estimate the total annual catch of the water resource under survey. Thus, fisher-days within a year in the water resource is the smallest unit of the populations. More precisely, the list of fishers and their active days of fishing—i.e., 'fisher-days' within a year define the sampling frame. The catch of a 'fisher-day' is the basic characteristics to be measured for the catch estimation. Like mentioned earlier, the list of any predefined region of a water resource complete the sampling frame. A few examples are as follows:

- a list of fisher-days of a wetland;
- a list of fisher-days of a reservoir;
- a list of fisher-days of a river's stretch or whole river.

The fishing intensity practically varies over time and locations, for example, seasons and water resources— a particular stretch of a long river. Thus, a natural subdivision of the population is spread over different stretches of rivers, water resources and seasons. If the objective is to obtain monthly catch data, the months create the strata. For simplicity, the methodology described here is specific to rivers and seasons. Technically, the population is stratified using the pair combination of stretch and season as stratification variables. The stratification is of a nested type, where the season is nested within a stretch. The number of strata is the product of the number of stretches and the number of seasons. The number of seasons may correspond to the number of months if the future aim is to estimate monthly catch data.

### 4.1.1 Mathematical form of population total catch

Imagine that catch or harvest records are available for all fishers, all active days of their fishing. In that case, the total catch is the sum of all catches of total available fisher-days over all the stretches. For a mathematical representation of the total fish catch or harvest, the following notation is defined.

$L$—the total number of stretches in the selected river aimed for estimation;

### 4.4.4 Calculation of the variance of the total fish catch estimate

**Step 1** Compute the average catch of each selected fisherman accounting the catch of sampled fishing days.

**Step 2** Calculate the difference between each sampled day's catch and the average catch (CPUE) for individual fisherman (Table 4.19).

**Step 3** Square each fishing day's catch difference and sum the square for all fishing days. Divide the sum by the number (total sampled fishing days -1) to get the sample variance for each fisherman.

**Step 4** Compute $\widehat{Var}\left(\hat{C}_{isf}\right)$ for each selected fisherman by following the formula $D_{isf}.\left(D_{isf} - d_{isf}\right)\frac{s_{isf}^2}{d_{isf}}$ as described in Table 4.19.

**Step 5** Take sum of $\widehat{Var}\left(\widehat{C_{isf}}\right)$ of all selected fisherman to get the total variance at 2nd stage sampling.

Table 4.19 Calculation of variance of total fish catch for 2nd stage sampling

| Sl. No. | Sampled fishing day | Sampled fisherman total catch (Kg) of Stretch 1 in lean season | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | F-1 | | F-2 | | F-3 | | F-4 | |
| | | $(C_{isfk})$ | $(C_{isfk} - \bar{C}_{isf})^2$ | $(C_{isfk})$ | $(C_{isfk} - \bar{C}_{isf})^2$ | $(C_{isfk})$ | $(C_{isfk} - \bar{C}_{isf})^2$ | $(C_{isfk})$ | $(C_{isfk} - \bar{C}_{isf})^2$ |
| 1 | 1 | 1.0 | 0.2916 | 1.2 | 0.8836 | 1.5 | 0.49 | 2.5 | 0.026 |
| 2 | 2 | 2.0 | 0.2116 | 1.9 | 0.0576 | 2.1 | 0.01 | 1.1 | 1.538 |
| 3 | 3 | 2.6 | 1.1236 | 2.0 | 0.0196 | 1.9 | 0.09 | 2.4 | 0.004 |
| 4 | 4 | 1.5 | 0.0016 | 2.6 | 0.2116 | 2.5 | 0.09 | 2.6 | 0.068 |
| 5 | 5 | 0.6 | 0.8836 | 3.0 | 0.7396 | 3.0 | 0.64 | 3.1 | 0.578 |
| **Average catch (kg) $(\bar{C}_{isf})$** | | **1.54** | | **2.14** | | **2.2** | | **2.34** | |
| $s_{isf}^2$ **= sum/(5-1)** | | | 0.628 | | 0.478 | | 0.33 | | 0.553 |
| $D_{isf}.(D_{isf} - d_{isf}).\frac{s_{isf}^2}{d_{is}}$ **=** | | | **31×(31-5) × 0.628/5 = 101.23** | | **31×(31-5) × 0.478/5 = 77.05** | | **31×(31-5) × 0.33/5 = 53.19** | | **31×(31-5) × 0.553/5 = 89.14** |
| **Total variance $\widehat{Var}\left(\widehat{C_{is}}\right)$ for 2nd stage sampling = 101.23 + 77.05 + 53.19 + 89.14 = 320.61** | | | | | | | | | |

**Step 6** After variance calculation of 2nd stage sampling, calculate variance of 1st stage sampling.

**Step 7** Calculate total catch of each sampled fisherman in the entire season.

**Step 8** Compute difference between total catch of each fisherman and average total catch of the season. Square the differences and sum for all sampled fishermen (Table 4.20).

**Step 9** Divide the Step 8 result by fisherman number (sampled fishermen no. - 1) to get the sample variance $s^2_{isb}$ (Table 4.20).

**Step10** Calculate variance of 1st stage sampling using formula $N_{is}.(N_{is} - n_{is})\frac{s^2_{isb}}{n_{is}}$ as shown in (Table 4.20).

**Step11** Sum the variance of two stages sampling to get the total variance for stratum 1 (Stretch 1+ lean season)

Table 4.20 Calculation of variance of total catch for 1st stage sampling

| Stretch 1 + Lean period | | |
|---|---|---|
| Sampled fisherman | Total catch (kg) in the season ($\hat{C}_{isf}$) | $\left(\hat{C}_{isf} - \bar{\hat{C}}_{is}\right)^2$ |
| F1 | 47.74 | 254.88 |
| F2 | 66.34 | 6.94 |
| F3 | 68.2 | 20.21 |
| F4 | 72.54 | 78.06 |
| **Average catch ($\bar{\hat{C}}_{is}$) =** | **63.705** | **Sum = 360.09** |
| $s^2_{isb} = \frac{1}{n_{is}-1}\sum_{f=1}^{n_{is}}\left(\hat{C}_{isf} - \bar{\hat{C}}_{is}\right)^2$ = 360.09/(4-1) =120.03 | | |
| Variance of 1st stage = $N_{is}.(N_{is} - n_{is})\frac{s^2_{isb}}{n_{is}}$ = 45× (45-4)×120.03/4 =55363.3 | | |
| Total variance = variance of 1st stage + variance of 2nd stage sampling = 320.61 + 55363.3 = 55683.9 | | |
| $RSE\ (\%) = \frac{\sqrt{55683.9}}{7684} \times 100 = 3.07\%$ | | |

**Step12** Repeat the above steps for calculating variance of 1st and 2nd stage sampling for each stratum.

**Step13** Sum all the variance of all stratum to get the total variance.

**Step14** Square root of the total variance (Step 13 result) divided by estimated total catch (7684 kg) and the result is multiplied with 100 to get the RSE of the estimate.

> **Note:** The implementation strategy describes the ratio method, which is, in general, more precise than the unbiased method. The demonstration was given for the case when the number of active fishing days is not available for the sampled fishers. It is strongly recommended to record the number of active fishing days for the sampled fishers, at least, and using the appropriate formula for estimation.

# 5 Catch estimation procedure for rivers and estuaries

Like marine fisheries, catch of estuarine fisheries can be intercepted at landing center. Thus, landing center approach can directly be implementable. Riverine fisheries, however, needs prior segregation of fishing activities for adopting suitable methodology. Fishery in rivers of the country is solely capture-based and open access with some exceptions where there are leased to co-operatives or private parties. It is a complex mix of commercial, artisanal, subsistence, and traditional fisheries with a highly dispersed and isolated nature of fishing; diverse fishing gears and tackles; migratory fishers, fish catch disposal right from fishing boats or from the fishing spot; the multispecies composition of the catches and their landing in unsorted conditions; and above all an unorganized marketing system. Thus, recording riverine fish catch, the number of fishers or boats is exceedingly difficult, except for those where well-defined landing centers exist in the rivers like the Ganga River. When well-defined landing center does exist, it is better to adopt the method for artisanal fishing described in the Chapter 1. The present chapter describes the typical catch estimation methods using landing center approach.

## 5.1 Sampling frame

The determination of the sampling frame, that is the list of defined smallest unit to be sampled, is the prerequisite of getting an estimate. Sampling and data collection should be carried out only from the predefined sampling frame. The district-level estimate is targeted in this methodology. The proposed method defines a landing centre or a market as the sampling unit, and fish catch of it is the measurable characteristic. Thus, the population consists of all the landing centres or markets—with the total annual catch of the landing centres or market (from now on referred to as landing centres) as the single population measurable characteristic to be estimated. Two strategies are adopted for a district-level estimate:

1. A single population includes all landing centres of all the rivers or estuaries. The district-level estimate is obtained straightforwardly.
2. The all the landing centers in the districts are segregated for rivers or estuaries, then estimates are obtained for all rivers or estuaries. Aggregated estimates for all the rivers then provide the district-level estimate of rivers and estuaries.

The first strategy incurs a relatively low cost and human resources compared to the second strategy; however, it fails to provide any river-specific or estuary-specific estimate. On the other hand, the second strategy can produce a river-specific or estuary-specific estimate, along with the district-level estimate of the river or estuary for the district targeted. Therefore, adopting strategies depends on the trade-off between cost, precision and types of estimates required.

## 5.2 Sampling method for the district without river or estuary specific estimate

Before devising the sampling method, it is essential to derive the population parameters to be estimated. Let's define the following variables:

$S$— the number of seasons—or periods suitably dividing the whole year; when the monthly estimate is desirable, then $S = 12$ corresponding to each month;
$L_s$—the number of active landing centres in the $s^{th}$ season in the district;
$D_{sl}$—the number of landing days in the $s^{th}$ season of $l^{th}$ landing centre; and
$C_{sld}$—be the catch landed on the $d^{th}$ day of $s^{th}$ season at the $l^{th}$ landing centre.

If catch or landing data were recorded for all landing days of each season at all landing centres, the calculation of total catch would easily be computed from the following equation(5.1)

$$Total\ annual\ catch\ of\ the\ district\ (\mathrm{C}) = \sum_{s=1}^{S}\sum_{l=1}^{L_s}\sum_{d=1}^{D_{sl}} C_{sld}. \qquad (5.1)$$

The above formula can be written as in equation(5.2),

**Step 5** For each selected landing centre, calculate the average catch over sample days to obtain the catch per day of the landing centre. Then, multiply the catch per day by the total number of landing-days of the landing centre to obtain the total seasonal catch of the landing centres.

**Step 6** Compute the average of season-specific total catch computed in the Step-5 over the sampled landing centres of the district, and then multiply it by the total number of effective landing centres in the concerned district to get the district-level total catch for a season.

**Step 7** Calculate the sum of the total catch computed in the Step-6 over all the season to obtain the total annual catch of the district and state.

***Illustration***

We present a hypothetical example of a state that has three districts. Fig. 5.2 shows the distribution of landing centers in all districts: the district 1 contains ten landing centres; the district 2 contains 10 landing centers; and the district 3 contains 3 landing centres.

**Step 1** Prepared a list of landing centres in each district as shown in Table 5.1

Table 5.1:List of fish landing centres

| District 1 | | District 2 | | District 3 | |
|---|---|---|---|---|---|
| Landing Centre | River Name | Landing Centre | River Name | Landing Centre | River Name |
| D1L1 | R 1 | D2L1 | R 1 | D3L1 | R 3 |
| D1L2 | R 2 | D2L2 | R 2 | D3L2 | R 3 |
| D1L3 | R 1 | D2L3 | R 3 | D3L3 | R 3 |
| D1L4 | R 1 | D2L4 | R 1 | | |
| D1L5 | R 2 | D2L5 | R 2 | | |
| D1L6 | R 1 | D2L6 | R 1 | | |
| D1L7 | R 1 | D2L7 | R 1 | | |
| D1L8 | R 2 | D2L8 | R 2 | | |
| D1L9 | R 2 | D2L9 | R 2 | | |
| D1L10 | R 1 | D2L10 | R 3 | | |

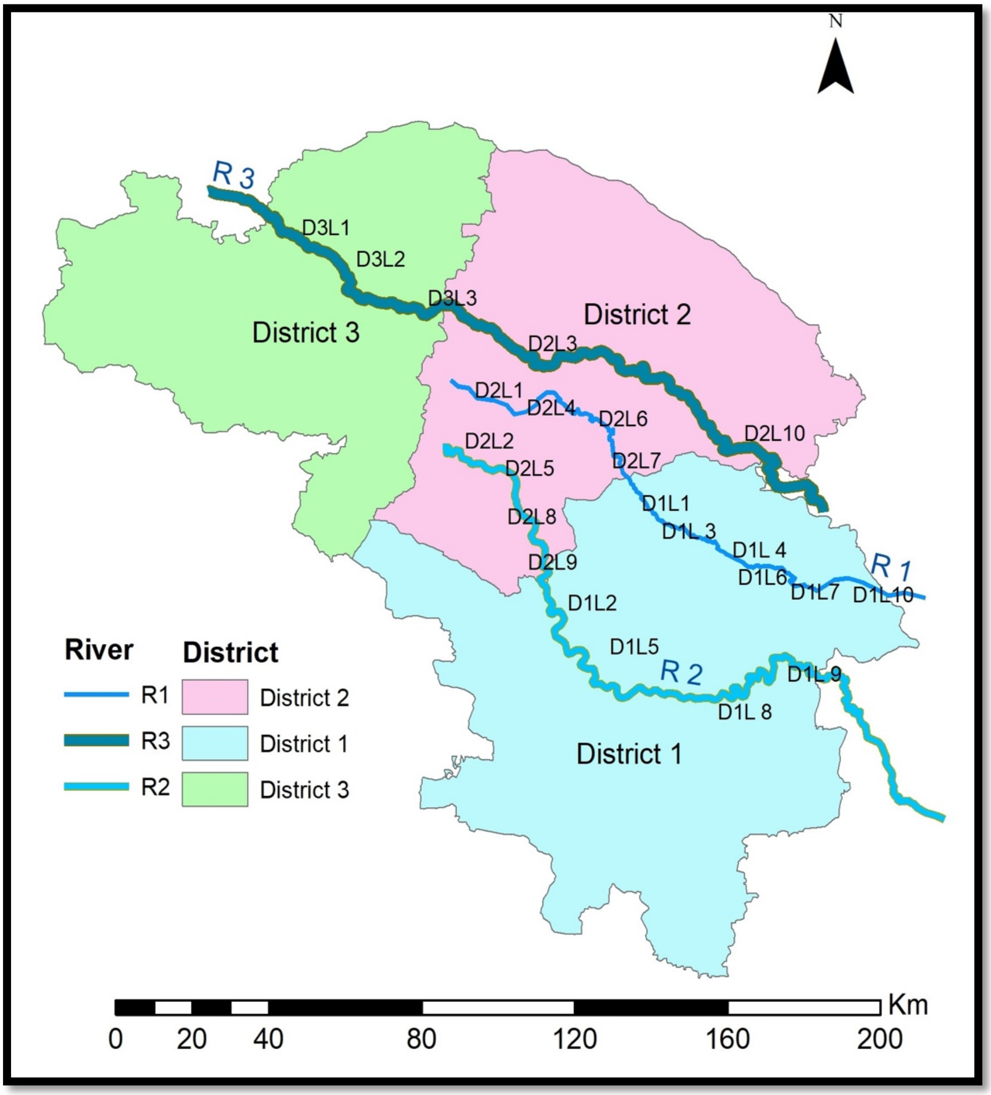



Fig. 5.2 Hypothetical map of state having three district and three river

**Step 2** For our example data, stratify the whole year into a few groups of period according to fishing intensity—e.g., peak(P), lean(L) and normal(N)., the list of landing-days for all the landing centers is prepared and presented in Table 5.2. The landing center D1L6 is excluded from the sampling frame. However, D2L6—the L6 landing center of the district 2—will not be considered for the lean season only.

Table 5.18 Variance between landing centers of district 1

| Season | Peak | Lean | Normal |
|---|---|---|---|
| River 1 stretch | | | |
| D1L1 | 9 | 484 | 121 |
| D1L3 | 256 | 324 | 25 |
| D1L10 | 169 | 289 | 25 |
| $s_{sb}^2$ | 217 | 549 | 86 |
| $L_s.(L_s - n_s)\dfrac{s_{sb}^2}{n_s}$ | 723 | 1830 | 287 |
| $\sum_{s=1}^{S} L_s.(L_s - n_s)\dfrac{s_{sb}^2}{n_s}$ [Component 1 of equation (5.4) for River 1 stretch] | | | =2840 |
| River 2 stretch | | | |
| D1L5 | 49 | 49 | 529 |
| D1L8 | 9 | 729 | 225 |
| D1L9 | 25 | 0 | 81 |
| $s_{sb}^2$ | 42 | 389 | 418 |
| $L_s.(L_s - n_s)\dfrac{s_{sb}^2}{n_s}$ | 56 | 519 | 557 |
| Component of 1 of equation (5.4) for river 2 stretch | | | =1132 |

Total Variance is given by equation (5.4)

$$\widehat{Var}(\hat{C}) = \sum_{s=1}^{S} L_s.(L_s - n_s)\frac{s_{sb}^2}{n_s} + \sum_{s=1}^{S}\frac{L_s}{n_s}\sum_{l=1}^{n_s} D_{sl}.(D_{sl} - d_{sl}).\frac{S_{sw}^2}{d_{sl}}$$

$$= component\ 1 + compnent\ 2$$

$$\widehat{Var}(\hat{C}) = 2840 + 5022675$$

$$= 5025515 \text{ for River 1 stretch}$$

Similarly, for River 2 stretch

$$\widehat{Var}(\hat{C}) = 1132 + 12096235$$

$$= 12097367$$

Total Variance of district 1 = $\widehat{Var}(\hat{C})$ *for river* 1 + $\widehat{Var}(\hat{C})$ *for river* 2

= 5025515+12097367

= 17122882

### *Relative standard error (RSE)*

Relative standard error (RSE) is the 'Standard error' divided by the estimated value and is expressed as a percentage. In present case standard error is 4138 for district 1 and total catch of district 1 is130087.

so RSE= $= \frac{standered\ error}{Total\ catch} \times 100 = \frac{4138}{130087} \times 100 = \mathbf{3.181}\%$

Similarly we can calculate RSE for District 2 and 3 which is 4.62% and 7.72

### *State level Relative standard error (RSE)*

State-level RSE can easily be computed, using the district level catch and the corresponding estimated variance. In the above illustration, we derived catch of three districts and the corresponding variance estimates are presented in the following table.

Table 5.19 State level Relative standard error

| District | | Component 1 | Component 2 | $Var(C)$ | Catch(in kg) |
|---|---|---|---|---|---|
| District 1 | River-1 | 2840 | 5022675 | 5025515 | 74185 |
| | River-2 | 1132 | 12096235 | 12097367 | 55902 |
| District 2 | River-1 | 3580 | 12560288 | 12563868 | 47518 |
| | River-2 | 1192 | 14798092 | 14799284 | 63649 |
| | River-3 | 306 | 7287492 | 7287798 | 16146 |
| District 3 | River-3 | 220 | 10428811 | 10429030 | 41838 |
| | | State Level Variance | | **62202862** | |
| | | State Level Catch | | | **299238** |

The state-level variance = sum of the variances of the districts

= 62202862

State Level Total Catch = 299238

State Level Standard Error = 7887

The state level RSE $= \frac{\text{The state−level stadered error}}{\text{State−level total catch}} \times 100$

$= \frac{7887}{299238} \times 100 = \mathbf{2.64\%}$

# 6 Catch estimation procedure for reservoirs

Reservoirs are all man-made water bodies created by barricading a flowing water body, such as streams, rivers, etc. Their area usually exceeds 10 ha. Some man-made impoundments created to store the local catchment are also included in these type of water bodies, but Ponds/tanks created for community use and fish culture are excluded.

Apart from the services provided by reservoirs for which they were created, they also play an important role in fish production and contribute substantially to the livelihoods and nutritional security of the communities that resided along their shores. Reservoir fisheries are basically extractive in nature and the strategy for their development is mainly formulated on capture fisheries (Jhingran, 1988). The size of a reservoir is an important criterion for determining the type of fisheries activities or fisheries management. Indian reservoirs are generally classified as small (10-1000 ha), medium (1000-5000 ha), and large (>5000 ha) based on their size. In India, reservoirs are generally managed for fisheries enhancement by adopting stock enhancement, species enhancement, culture-based fisheries, or other forms of enhancement, depending on the bio-physical nature of the water body. In small reservoirs characterized by the near-total drawdown of water, culture-based or we can say extensive aquaculture, capture fisheries along with culture-based fisheries are the common characteristics of fisheries. In a culture-based fishery, stocking is done with the aim of recapturing a substantial part of the stocked fish which is possible only in relatively shallow reservoirs that are conducive to the operation of fishing gear and with low predator pressure. Medium and large reservoirs are amenable to stock enhancement, species enhancement, and new culture techniques i.e., pen and cage culture because stocking to recapture of fishes in these reservoirs becomes uneconomic. Hence, the characteristics of fisheries in medium and large reservoirs are mostly capture-based except for the harvest from enclosure culture.

Fisheries in Indian reservoirs are mostly managed by the respective state departments, fisheries cooperatives, and private agencies/fishermen on a lease/license basis. Fishing in reservoirs is diverse in nature viz. free fishing or open access fishing, outright auctioning, licensed fishing, departmental fishing, etc. In a vast majority of Indian reservoirs, where the catch is not very remunerative, no boats are used and the fisherman depends entirely on improvised devices like rafts of discarded old tyres, logs, used can, etc. The use of active fishing gear in the reservoirs is restricted due to the presence of underwater obstacles, hence the most common gear in use is gill nets and drag or seine nets mostly in small reservoirs which are relatively shallow. Other fishing gears employed in reservoirs are long lines, hand lines, pole and lines, cast nets, etc., however, their contribution to the total catch is very insignificant. Other than the capture fishery, there is regular fish harvesting from the reservoirs where the enclosure culture such as pen and cage culture are practiced and data recording of which may be easier and more precise. Routine fish catch data is recorded in some reservoirs where culture-based fisheries or fish stock enhancement is adopted and managed by the state fisheries department, fisheries co-operatives, and lessee. Whereas the catch data recording is limited or negligible in the unmanaged reservoirs or in the reservoirs where only artisanal or subsistence fisheries take place.

## 6.1 Sampling frame

The sampling methodology adopted for these waterbodies is stratified two-stage sampling. The fisheries and catch vary according to the type of waterbodies. Like rivers and estuaries, the proposed method suggests the district level catch estimation. The chapter describes the methodology considering landing-days as the smallest population units. The same idea can be adopted when the smallest population units are fisher-days, when fishers are easier to access than to the landing centers. In absence of landing centers, the method of artisanal fishing described in Chapter 1 can be adopted, where the fishers-days are the smallest population units to be sampled.

, where $r$ is the yield rate—catch per unit area (e.g. ha) per year and $A$ is the total area of all the reservoir of the concerned group—e.g., small, medium, and large. The computation of $r$ is straightforward: divide the total estimated catch from the entire sampled reservoir by the total area of the entire sampled reservoir. The variance of the estimate can be estimated using the same formula given in equation (6.7), after replacing $\hat{C}$ with $(r \times A)$, the equation is given in (6.9).

$$s_{br}^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(\hat{C}_i - \hat{r}.A_i\right)^2 \tag{6.9}$$

## 6.3 Step-wise procedural description

**Step 1** Prepare the complete list of reservoirs and record their area in the district.

**Example:** *The Ranchi district of Jharkhand is taken here as an example data. Department of Fisheries, Jharkhand enlisted the total 28 reservoirs along with their areas. They were delineated and presented in GIS (Fig. 6.2) for planning of data collection strategy. The perquisite list is prepared that is shown in*

Table 6.1. *This is the first step that is to be followed by each district-level fishery office.*

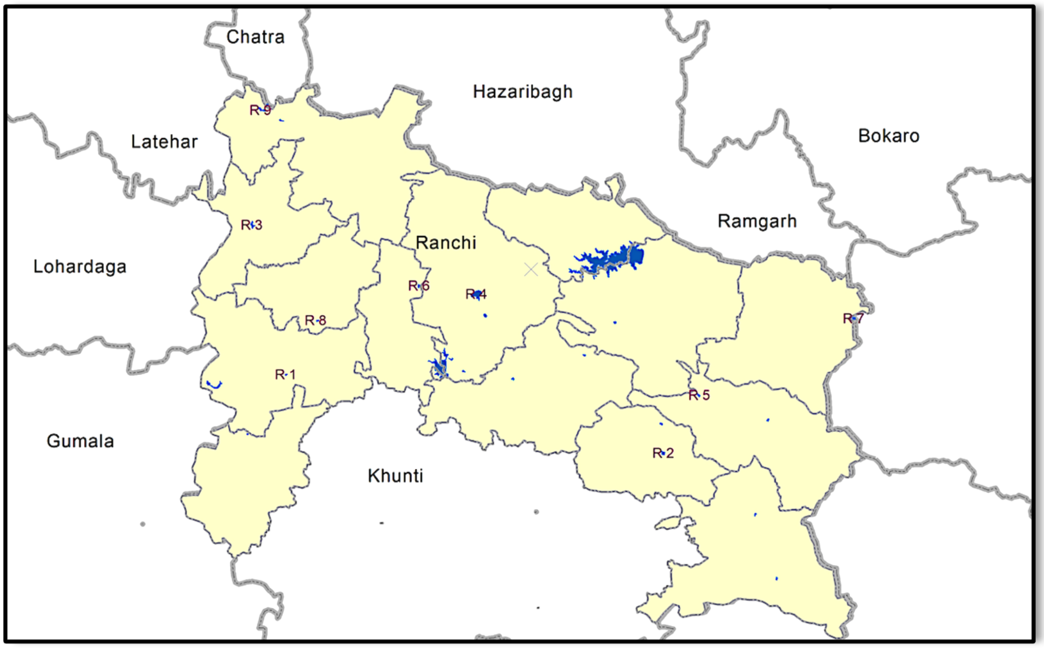



Fig. 6.2 Map of District Ranchi with block boundaries and reservoirs

So component 1 will be zero. Computation for variance within a landing centres over landing days is given in Table 6.13

Table 6.13 Computation of variance estimates of medium reservoir

| | L1 | | | L2 | | | L3 | | |
|---|---|---|---|---|---|---|---|---|---|
| Season | P | N | L | P | N | L | P | N | L |
| Average $\bar{C}_{ils}$ | 235 | 95 | 24 | 251 | 122 | 24 | 250 | 105 | 21 |
| $(C_{ils1}-\bar{C}_{ils})^2$ | 841 | 1936 | 0 | 36 | 36 | 1 | 784 | 1681 | 1 |
| $(C_{ils2}-\bar{C}_{ils})^2$ | 121 | 1296 | 25 | 361 | 1 | 25 | 400 | 441 | 1 |
| $(C_{ils3}-\bar{C}_{ils})^2$ | 324 | 1024 | 4 | 1089 | 484 | 1 | 676 | 16 | 9 |
| $(C_{ils4}-\bar{C}_{ils})^2$ | 36 | 1444 | 4 | 1521 | 121 | 1 | 2500 | 121 | 25 |
| $(C_{ils5}-\bar{C}_{ils})^2$ | 625 | 1444 | 4 | 49 | 400 | 1 | 1089 | 9 | 4 |
| $(C_{ils6}-\bar{C}_{ils})^2$ | 324 | 4 | 16 | 625 | 25 | 4 | 529 | 144 | 121 |
| $(C_{ils7}-\bar{C}_{ils})^2$ | 441 | 1225 | 16 | 1024 | 100 | 16 | 324 | 1156 | 9 |
| $s^2_{ils}$ | 452 | 1396 | 12 | 784 | 195 | 8 | 1050 | 595 | 28 |
| $D_{ils}$ | 52 | 32 | 56 | 30 | 36 | 56 | 50 | 39 | 44 |
| A* | 151097 | 159543 | 4704 | 77280 | 29083 | 3136 | 322500 | 106080 | 6512 |
| | **L4** | | | **L5** | | | **L6** | | |
| Average $\bar{C}_{ils}$ | 239 | 104 | 26 | 246 | 89 | 25 | 248 | 94 | 25 |
| $(C_{ils1}-\bar{C}_{ils})^2$ | 49 | 1 | 1 | 9 | 1521 | 25 | 81 | 100 | 81 |
| $(C_{ils2}-\bar{C}_{ils})^2$ | 25 | 0 | 81 | 25 | 16 | 1 | 121 | 81 | 4 |
| $(C_{ils3}-\bar{C}_{ils})^2$ | 81 | 9 | 36 | 64 | 400 | 4 | 49 | 441 | 16 |
| $(C_{ils4}-\bar{C}_{ils})^2$ | 196 | 1521 | 1 | 529 | 4 | 4 | 64 | 529 | 0 |
| $(C_{ils5}-\bar{C}_{ils})^2$ | 225 | 784 | 25 | 25 | 625 | 36 | 361 | 289 | 25 |
| $(C_{ils6}-\bar{C}_{ils})^2$ | 256 | 100 | 0 | 4 | 576 | 4 | 961 | 9 | 9 |
| $(C_{ils7}-\bar{C}_{ils})^2$ | 1764 | 25 | 9 | 784 | 4 | 0 | 400 | 16 | 0 |
| $s^2_{ils}$ | 433 | 407 | 26 | 240 | 524 | 12 | 340 | 244 | 23 |
| $D_{ils}$ | 48 | 23 | 52 | 140 | 83 | 77 | 109 | 63 | 78 |
| A* | 121735 | 21397 | 8691 | 638400 | 472199 | 9240 | 540017 | 122976 | 18196 |
| B* of L1 | | 315344 | | B* of L2 | | | | 109499 | |
| B* of L3 | | 435092 | | B* of L4 | | | | 151823 | |
| B* of L5 | | 1119839 | | B* of L6 | | | | 681189 | |
| $\sum_{l=1}^{L_i}\sum_{s=1}^{S} D_{ils}.(D_{ils}-d_{ils}).\frac{s^2_{ils}}{d_{ils}}$ | | | | = 315344 + 109499 + 435092 + 151823 + 1119839 + 681189 = 2812786 | | | | | |

$$A^* = D_{ils}.(D_{ils}-d_{ils}).\frac{s^2_{ils}}{d_{ils}} \qquad B^* = \sum_{s=1}^{S} D_{ils}.(D_{ils}-d_{ils}).\frac{s^2_{ils}}{d_{ils}}$$

In this example there is only one reservoir so the component 1 is zero and N =1 and n=1

$$\hat{V}ar(\hat{C}) = 2812786$$

Standard error $= \sqrt{\hat{V}ar(\hat{C})} = \sqrt{2812786} = 1677$

Total catch =141261kg

RSE $= \frac{standard\ error}{Total\ catch} \times 100$

# 7 Catch estimation procedure for floodplain wetlands and lakes

Floodplain wetlands are defined as the lentic water bodies adjoining to rivers—with or without connection—e.g., oxbow lakes, beels, chaurs, hoars, mauns, taals, bheries etc. Lakes include lagoons, kayals, and all freshwater lakes—including upland lakes. In the wetlands, especially the floodplain wetlands, capture fishery was the only existing fishery before the 1960s. Wetland fisheries characteristics dramatically changed after adopting stocking as the main policy for inland open water fisheries management in India (Sugunan, 1995). The floodplain wetlands are getting disconnected from their parent river due to the several geogenic and anthropogenic factors, such as altered flow, hydrological changes of rivers, human intervention/settlement in the catchment area, etc., that have restricted the free migration of fishes to the parent river and vice-versa, thereby limiting the self-recruiting fish population in the wetlands. With time, besides capture fisheries, culture-based fisheries, stock enhancement, and new culture systems or enclosure cultures are becoming the common characteristics of fisheries in Indian wetlands. Characteristics of wetland fisheries vary with the types of wetlands. In the case of closed wetlands, for instance, other than capture fisheries, the culture-based fishery is the main fishery wherein the stocking and harvesting are practiced, as because auto-stocking or self-recruiting fish population is unable to sustain the fishery (De Silva, 2015). On the other hand, capture fisheries—harvesting of the natural fish stock—prevail in perennially open and large or seasonally open wetlands; however, stock enhancement, culture-based fisheries, and enclosure culture gradually become a part of fisheries in such wetlands. Currently, wetland fishery exclusively based on capture fisheries is becoming rare primarily due to the declining fish catch rates in wetlands. Fish catch in managed wetlands is mainly congregated in a single place as most of these wetlands are managed by fishermen co-operatives or lessees, hence recording of fish catch data is comparatively easier and often recorded by the co-operatives or lessees. On the other hand, catch in unmanaged wetlands (small, weed-choked, closed) is landed in a very dispersed manner as fishing in such wetlands takes place only for subsistence and very often goes unreported. The fish catch estimation would be more accurate if we could collect catch data specific to the types of wetlands considering the varied nature of fisheries or fisheries management or fish recruitment in different types of wetlands.

The sampling procedures are same for lakes and wetlands. However, it is suggested to obtain separate estimates for lakes and wetland for better management practices, and partitioning variability across types of water bodies. The chapter describes the methodology considering landing-days as the smallest population units. The same idea can be adopted when the smallest population units are fisher-days.

## 7.1 Sampling frame

As mentioned earlier, designing sampling frame is before carrying out statistical survey. A schematic diagram (Fig. 7.1) presents the sampling frame for landing center approach of fish catch estimation. The first stage units are wetlands or lakes from which a sample of suitable size is to be selected randomly. The second-stage units are fishing days, precisely, landing days. Unlike method proposed for river and estuaries, complete enumeration is proposed for landing centers, that means all the landing centers in the selected wetlands are to be surveyed. Like other method mentioned earlier, the seasons are categorized according the fishing intensity. Thus landing days within a season and landing center constitute the second stage unit.

## 7.2 Formulae for estimation

The sampling procedure is same as that described for reservoirs, except grouping according to area. Hence, the derivation of formulae is similar. Let's define the following quantities:

$N$—the total number of wetlands or lakes in the districts;

$n$—the number of wetlands selected randomly; $n$ must be greater than 3;

$L_i$—the total number of landing centres in the $i^{th}$ wetland;

$S$— the number of seasons or periods, e.g., peak, lean and normal, suitably dividing the whole year; For monthly catch estimation, S = 12.

**Step 1** The sampling frame for the first-stage units is recorded, which is the list of total 28 wetlands in the district and presented in the Table 7.1.

Table 7.1 List of wetlands in district Vaishali

| Sl. No. | Name Of Wetland | Water Area (ha) | Wetland code | Sl. No. | Name Of Wetland | Water Area (ha) | Wetland code |
|---|---|---|---|---|---|---|---|
| 1 | Wetland 1 | 23.12 | W1 | 15 | Wetland 15 | 49.81 | W15 |
| 2 | Wetland 2 | 15.13 | W2 | 16 | Wetland 16 | 157.27 | W16 |
| 3 | Wetland 3 | 12.55 | W3 | 17 | Wetland 17 | 56.77 | W17 |
| 4 | Wetland 4 | 84.84 | W4 | 18 | Wetland 18 | 134.08 | W18 |
| 5 | Wetland 5 | 27.01 | W5 | 19 | Wetland 19 | 415.04 | W19 |
| 6 | Wetland 6 | 135.48 | W6 | 20 | Wetland 20 | 51.34 | W20 |
| 7 | Wetland 7 | 40.23 | W7 | 21 | Wetland 21 | 41.04 | W21 |
| 8 | Wetland 8 | 55.36 | W8 | 22 | Wetland 22 | 112.24 | W22 |
| 9 | Wetland 9 | 11.94 | W9 | 23 | Wetland 23 | 284.27 | W23 |
| 10 | Wetland 10 | 24.63 | W10 | 24 | Wetland 24 | 15.38 | W24 |
| 11 | Wetland 11 | 54.54 | W11 | 25 | Wetland 25 | 68.01 | W25 |
| 12 | Wetland 12 | 20.23 | W12 | 26 | Wetland 26 | 13.18 | W26 |
| 13 | Wetland 13 | 225.71 | W13 | 27 | Wetland 27 | 31.73 | W27 |
| 14 | Wetland 14 | 99.03 | W14 | 28 | Wetland 28 | 15.61 | W28 |
| | **Total Area of wetlands** | | | | | **1860 ha** | |

**Step 2** As a rule of thumb, select 25 – 30% of the wetlands. Thus, the sample size is rounded off to 9 (= 28 ×0.30) because total 28 wetlands are in the district.

Table 7.2 : List of selected wetlands.

| Sl. No. | Name Of Wetland | Water Area (ha) | Wetland code |
|---|---|---|---|
| 1 | Wetland 4 | 84.84 | W4 |
| 2 | Wetland 21 | 41.04 | W21 |
| 3 | Wetland 13 | 225.71 | W13 |
| 4 | Wetland 28 | 15.61 | W28 |
| 5 | Wetland 26 | 13.18 | W26 |
| 6 | Wetland 20 | 51.34 | W20 |
| 7 | Wetland 14 | 99.03 | W14 |
| 8 | Wetland 23 | 284.27 | W23 |
| 9 | Wetland 15 | 49.81 | W15 |
| | **Total Area** | **864.83** | |

**Step 3** In this example no annual catch data is readily available so landing centre approach is followed.

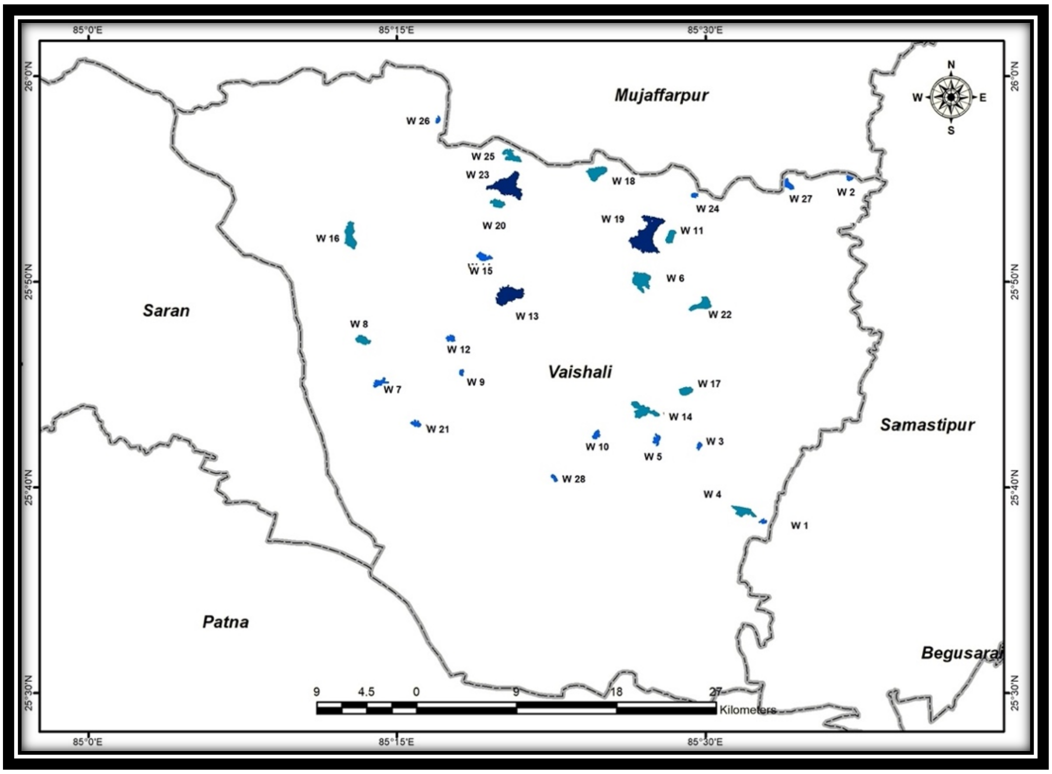



Fig. 7.2 Map of district Vaishali with wetlands.

**Step 3.1** Make a list of all the landing centres/market of the sampled wetlands Wetland/ lakes (Table 7.3). For each landing centre, divide the whole year in three periods: lean, peak, and normal season. Record the number of fishing days for each season at each landing centre/market. Now on ward peak season is denoted by **P** normal season by **N** and lean Season by **L** in the all the tables.

Table 7.3 : List of Selected Landing Centres with landing days in different season

| Wetland code | Landing Center | Landing-days | | |
|---|---|---|---|---|
| | | P | N | L |
| | L1 | 36 | 92 | |
| W4 | L2 | 40 | 108 | 102 |
| | L3 | 31 | 104 | |
| W21 | L1 | 32 | 89 | 89 |
| | L2 | 28 | 121 | |
| | L1 | 24 | 96 | 109 |
| W13 | L2 | 37 | 79 | |
| | L3 | 32 | 107 | 157 |
| | L4 | 29 | 103 | |

| | | | | | |
|---|---|---|---|---|---|
| W23 | 102290 | 440223 | 174338 | 179240 | 896091 |
| W15 | 366300 | 432184 | | | 798484 |
| | $C^*$ | | | | 5651173 |
| | Component 2=$\frac{N}{n}C^* = \frac{28}{9}5651173$ | | | | **=17581427** |

$\mathbf{A}^*=\sum_{s=1}^{S} D_{ils}.(D_{ils}-d_{ils}).\frac{s_{ils}^2}{d_{ils}}$: $\mathbf{B}^*=\sum_{l=1}^{L_i}\sum_{s=1}^{S} D_{ils}.(D_{ils}-d_{ils}).\frac{s_{ils}^2}{d_{ils}}$

$\mathbf{C}^*=\sum_{i=1}^{n}\sum_{l=1}^{L_i}\sum_{s=1}^{S} D_{ils}.(D_{ils}-d_{ils}).\frac{s_{ils}^2}{d_{ils}}$

### *Calculation of Component 1*

Calculate $s_{br}^2$ as given in equation (7.7) as shown in Table 7.11, column 2 is the annual estimated catch of the sampled wetlands and column 3 is square of difference in average catch and estimated catch of the wetland.

Table 7.11: Calculation of variance between wetlands $s_{br}^2$

| Wetland | Catch (C) | $\left(C_i - \frac{\sum_{i=1}^{n} C_i}{n}\right)^2$ |
|---|---|---|
| W4 | 32235 | 41809156 |
| W14 | 27136 | 1868689 |
| W13 | 41892 | 259951129 |
| W23 | 45436 | 386790889 |
| W21 | 20690 | 25796241 |
| W20 | 20042 | 32798529 |
| W15 | 23608 | 4669921 |
| W28 | 11404 | 206353225 |
| W26 | 9474 | 265527025 |
| **Average Catch $\hat{C}$** | **25769** | |
| $\sum_{i=1}^{n}\left(\hat{C}_i - \frac{\sum_{i=1}^{n}\hat{C}_i}{n}\right)^2$ | | =1225564804 |
| $s_{br}^2$ | | =153195601 |
| Component 1 $(N.(N-n).\frac{s_{br}^2}{n})$ | | **=9055562163** |

Now,

$$\hat{V}ar(\hat{C}) = component1 + componenet\ 2$$
$$= (9055562163 + 17581427)$$
$$=9072949193$$

Standard error is Square root of total variance $(\hat{V}ar(\hat{C}))$ $=\sqrt{9072949193} = 95252$

Relative standard error (RSE) is the 'Standard error' divided by the estimated value and is expressed as a percentage. In present case standard error is 95252 for district and total catch of district is 721532

So, RSE= $= \frac{standard\ error}{Total\ catch} \times 100 = \frac{95252}{721532} \times 100 = 13.2\%$

## 7.5 Variance estimate for the estimated total catch using yield method in a district

### *Calculation of Component 1*

Calculate average yield from Table 7.7 as shown in Table 7.12 and $s_{br}^2$.

Table 7.12: Calculation of variance between wetlands ( $s_{br}^2$)

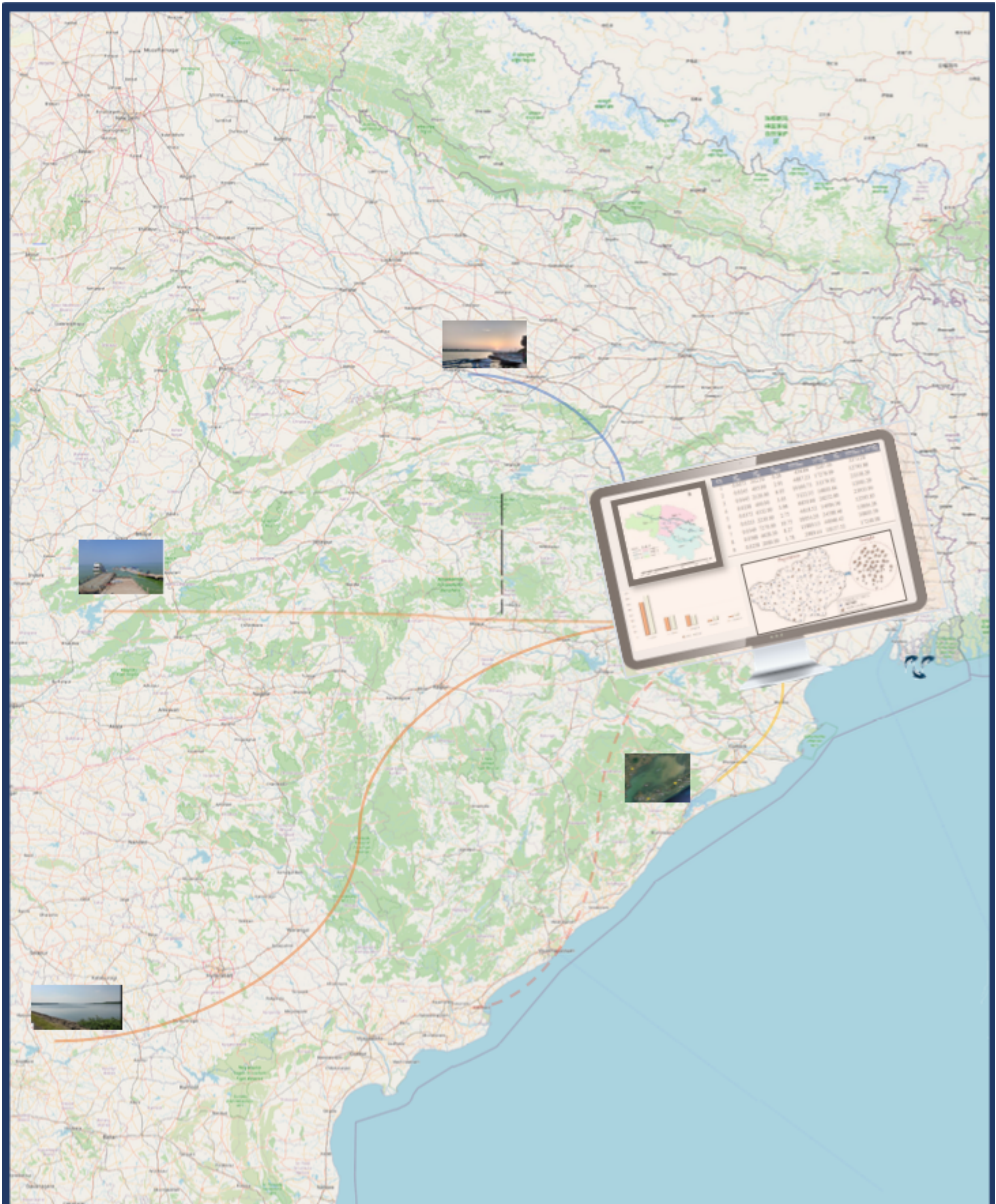
| Wetland | Catch $(C)$ | Area $(A)$ | $(C_i - rA_i)^2$ |
|---|---|---|---|
| W4 | 32235 | 84.84 | 90209724 |
| W14 | 27136 | 99.03 | 355168 |
| W13 | 41892 | 225.71 | 345896019 |
| W23 | 45436 | 284.27 | 945461643 |
| W21 | 20690 | 41.04 | 93920908 |
| W20 | 20042 | 51.34 | 39474581 |
| W15 | 23608 | 49.81 | 105245440 |
| W28 | 11404 | 15.61 | 52135909 |
| W26 | 9474 | 13.18 | 35304512 |
| **Total** | **231917** | **864.83** | |
| Average yield $\hat{r} = \frac{total\ estimated\ catch\ of\ sampled\ wetland}{total\ water\ area\ of\ sampled\ wetland}$ | | | $\frac{231917}{864.83}$ =268 |
| $\sum_{i=1}^{n}(\hat{C}_i - \hat{r}A_i)^2$ | | | =1708003904 |
| $s_{br}^2$ | | | =213500488 |
| Component 1 $(N.(N-n).\frac{s_{br}^2}{n})$ | | | **12620251068** |

Now,

$$\hat{V}ar(\hat{C}) = component1 + componenet\ 2$$
$$= (12620251068 + 17581427)$$
$$= 12637832496$$

Standard error is Square root the total variance ($\hat{V}ar(\hat{C})$)

$\sqrt{12637832496} = 112418$



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