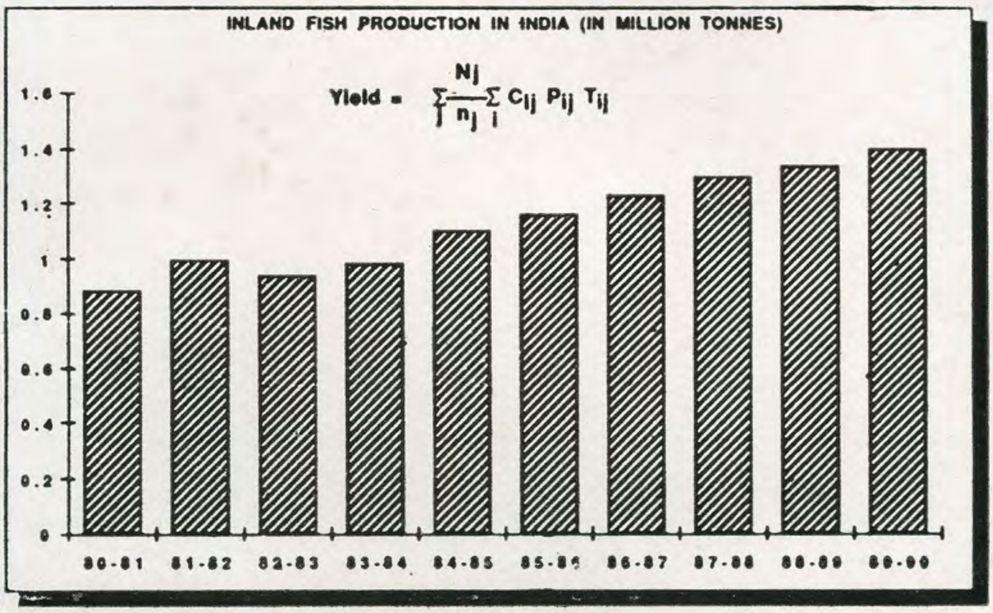
Methodology for Collection and Estimation of Inland Fisheries Statistics in India



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CENTRAL INLAND CAPTURE FISHERIES RESEARCH INSTITUTE
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FOREWORD

Creation of a sound and reliable data base on the country's natural and human resources is a pre-requisite for any meaningful developmental planning. Although India has a historical tradition in data collection and utilisation, their accessibility, reliability and compatibility in situations pertaining to inland fisheries is far from satisfactory as they are mostly region or project-specific. Unless a reliable and suitably chosen data collection system is evolved it is difficult, if not impossible, to have realistic targets of productivity and production.

For successful data acquisition methodology, it is imperative that data are accurately collected, processed, tabulated and integrated. Further, terms and concepts need to be explained explicitly without any ambiguity. The long felt need of a system for strengthening and streamlining the data collection culminated in 1984 in a centrally sponsored scheme and it was appropriately entrusted to CICFRI, Barrackpore. In furtherance of this objective, plans were made to prepare a Manual on Collection and Estimation Methodology of Inland Fisheries Statistics in India for the use of fishery survey workers in the country. The encouraging response with which the first edition of this manual was received, provided the necessary stimulus to the authors to incorporate diverse viewpoints that emerged from the assessment of the manual made by a good number of planners, development managers, researchers and eminent statisticians.

There can be no doubt about the usefulness of this Manual which covers many unusual features such as conceptualisation of terms and description of appropriate methods of estimation that are even now taking shape. I hope this revised and enlarged edition of the Manual will be of great operational significance for day-to-day working in the field and will further facilitate the planning process by ensuring the supply of requisite data in respect of inland fisheries.

(P.V. Dehadrai)

PREFACE

Development of a sound and reliable data base in inland fisheries has been receiving attention of the planners and management experts in the recent past. This arises partly from the general concern of the planners for fixing up targets and partly for making potential use of the available resources. To build up a reliable data base it is essential that a reasonably sound data collection and estimation methodology is evolved based on scientific lines and the same is put to practice for assessing the nature and quantity of inland fishery resource at the national level. A centrally sponsored scheme was launched to fulfil the long felt need for evolving a standardised methodology with research, guidance and implementation entrusted to CICFRI, Barrackpore.

Since the inception of the scheme it was recognised that a manual containing methods of collection of inland fisheries statistics was the foremost task of the Project. The published literature on the subject was too inadequate to be of any use in this regard and hence the first edition of the manual containing conceptual framework and methods was brought out. However, during the course of work a number of improvements were made in the methodology and these modifications have been incorporated in this revised edition.

The basic purpose of the manual is to provide guidelines on collection of data and make available suitable statistical tools to work out estimates with associated degree of reliability.

It is hoped that the publication will immensely help the survey officers in planning and implementation of the technical work programme in order to assess inland fishery resources and fish production to an appreciable degree of reliability at the national level.

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CHAPTER—1

INTRODUCTION

Economic planning has been considered as an important instrument of economic development in the developing world. A pre-requisite for sound planning is an extensive survey of the existing and potential resources of the country together with its deficiencies. As Baykov puts it "Every act of planning, in so far it is not mere fantastic castle building, presupposes a preliminary investigation of existing resources". Such a survey is essential for the collection of statistical data and the information with regard to the total available material, capital and human resources of the country. Data pertaining to the available and potential natural resources along with degree of their exploitation, agricultural and national output, transport, technical and non-technical personnel etc. are essential for fixing targets and priorities in planning.

There are several stages involved in the planning process viz., review and understanding, problem formulation, setting up of goals and objectives, possible choice of action, evaluation of the alternative choices, implementation, and control with periodical reviews. Several functionaries at various levels of the Government and other corporate bodies are actively involved in the decision making process regarding planning and development of fisheries. The success is largely dependent on quality of data/information, their timely availability, comparability and reliability. Although the collection of agricultural statistics in India has a long tradition, the importance of fisheries statistics was recognised only in recent years. Most of the debate on lack of data base in fisheries has been in the nature of a lament rather than a concrete policy. Therefore, it has been rarely appreciated that inland fishery activity, being atomistic in nature, makes the task of data collection more difficult than the collection of crop and industrial statistics. The need for strengthening the data base in fisheries was reemphasised by the working group for the formulation of IVth Five Year Plan on agricultural statistics (1965) and data improvement committee set up under the Chairmanship of Dr. B. S. Minhas, and a National Commission on Agriculture (1976).

CHAPTER—2

AN OVERVIEW

2.1 CURRENT STATUS OF INLAND FISHERIES STATISTICS

Before a case is made out for streamlining, improving and building data base in inland fisheries, it will be essential to have a broad inkling into the current inadequacies. Non availability of sound and reliable basic statistics has crippled the government and policy makers in planning and successful management of potentially rich water resources of our country. The question of collection, coordination and improvement of the basic information has been receiving the attention of both Central and State Governments as well as other organizations for a long time.

The Departments of fisheries in the States and Union territories have their statistical cells which collect and compile data through their field staff in accordance with the concepts and definitions provided by the FAO and other organizations. The data currently being compiled, though not on systematic basis by these organizations, cover most of the categories of water resources. These estimates are based on certain factors like lease amount, issue of licences, departmental exploitation, market arrivals, transactions of cooperatives etc. Still there is acute need for developing a uniform and standardised methodology for estimation of different types of inland fisheries resources.

Realising the need, a pilot investigation was launched in 1955-56 by ICAR in two districts of erstwhile Hyderabad state for developing suitable sampling techniques for inland fisheries. Later on, the Government decided to transfer the work from ICAR to the Directorate of National Sample Survey (NSSO) in April 1956. In September, 1958, the Directorate of the National Sample Survey took up the survey work in Orissa to evolve suitable sampling techniques for estimation of fish production. By the end of 1958, certain basic information such as various resources of inland fisheries and their relative importance, availability of sampling frame, fishing practices and availability of suitable agency for field work were collected, which later on formed the basis of the pilot survey in Orissa during 1962-63.

The NSSO undertook in 1962-63 pilot survey of inland fisheries in Orissa in 3 districts viz. Cuttack, Sambalpur and Mayurbhanj, based on the technical programme given by IASRI, New Delhi. The primary objective of the survey was to develop suitable methodology for the estimation of (i) number and area of ponds, tanks and swamps and (ii) total catch of fish therefrom. The information was collected mainly by enquiry and in some cases by physical verification.

An attempt was made by ISI, Calcutta, West Bengal for evolving sampling methodology for inland fisheries during 1960-61. The study gave some awareness of the field problems. The sampling work was seriously disturbed and no estimation was attempted on it.

The Central Inland Capture Fisheries Research Institute, Barrackpore made an attempt to estimate the area and catch from ponds in the district of Hooghly, West Bengal during 1962-63. But the survey could not be continued due to some administrative difficulties. In 1973-75, the NSSO conducted a survey covering 3 districts one each in West Bengal, Tamil Nadu and Andhra Pradesh with the aim at obtaining estimate of catch both from impounded water as well as riverine resources by enquiry method only. The estimates worked out were not satisfactory, particularly from the riverine resources.

In another pilot survey conducted jointly by IASRI, New Delhi and CICFRI, Barrackpore in one district of West Bengal during 1978-81, the data were collected both by enquiry and by physical observations. The main objectives of the survey were (1) to evolve suitable sampling methodology for estimation of (a) inland water resources and (b) total catch of inland fisheries and (2) to study the prevailing practices of pisciculture. The study covered only ponds in the district of 24-Parganas in West Bengal. The catch estimate of other important resources viz. estuaries, rivers, brackishwater impoundments, beels etc. could not be attempted due to limited manpower. Inspite of all these attempts, there is no scientifically designed method for collection and estimation of all types of inland fishery resources.

2.2 ROLE OF CICFRI

Taking note of vast potential in our country to increase inland fish production and at the same time to improve the socio-economic condition of indigent fishermen, the Government of India decided to get information on in inland areas suitable for pisciculture as well as fisheries development. They also wanted to know the present level of inland fish production so as to have an idea about the gap that exists between the present production and future potential in order to plan for proper management of these resources. In this connection, Government of India identified CICFRI, the nodal Institute in the inland fisheries research in India to be responsible for evolving a suitable sampling scheme for this purpose in collaboration with the State Governments. They also formed a Technical Evaluation Committee to advise or suggest suitable sampling methodology and to evaluate the work done by CICFRI in this regard. This resulted in a modest and bold beginning with the launching of the Central Sector Scheme in 8 States with CICFRI as coordinating agency.

2.3 OBJECTIVES OF THE SURVEY

The objectives of the survey are :

1. To develop uniform concepts, definitions and terminologies for various inland fishery resources.

2. To develop a suitable and standardised methodology for collection and estimation of inland fishery resources.

CHAPTER—3

CONCEPTUAL FRAMEWORK OF DATA BASE

3.1 INTRODUCTION

Inland fisheries are traditionally classified into capture and culture fisheries, the former being mainly exploitive of natural populations and the latter affording enough room for intense human intervention by stock control and other management practices. At present, the data base on inland fishery resources and their exploitation is infirm and inadequate making the task of planners difficult for a realistic estimation of resource and aquatic production. Even market intelligence statistics suffer from various drawbacks due to disposal of appreciable quantity of catch which passes directly from the primary producers to consumers or use of catch on the occasion of community feasts in the villages. Hence, a methodology of collection and estimation need to be evolved which should take into consideration such lacunae and provide a reasonable estimate which may be used for development planning and management of the resource. There exist wide variations in fish yield from different classes of aquatic ecosystem in the country. The annual yield from a unit area of an intensively managed fish pond can be as much as thousand times that of an average annual fish catch from a reservoir. Even fisheries which are not well-managed can also show variation by a factor of more than a thousand in yields depending upon where they are located and the prevailing ecological conditions. Therefore, information available on the fish yields associated with different kinds of ecosystem in India justifies the importance as also the need for evolving a strategy for collection of data which may give reliable and meaningful estimates for these different classes. For estimating the yields from various inland aquatic ecosystem, it is very much essential to classify them in different production regimes with their proper definitions and terminologies which could be followed uniformly throughout the country. At present, the degree of variation in respect of use of their terminologies relating to various inland water bodies in different parts of the country is quite confusing, making the task of data collection and estimation more difficult. It is evident that a water body classified as a tank in a particular region may be referred to as a pond in the other region. Furthermore, confusion also prevails in differentiating a large community pond and irrigation tank from a reservoir. As the fish yield from a reservoir varies appreciably due to different nature of the ecosystem, it is important to follow uniform concepts and terminologies for the inland fisheries resources to make the data collection and yield estimation more simple and meaningful. In view of this the entire fisheries resources have been classified into the following categories.

3.2 CLASSIFICATION OF INLAND FISHERY RESOURCES

1. Freshwater ponds and tanks
2. Lakes
3. Floodplain lakes
4. Rivers
5. Reservoirs
6. Estuaries
7. Brackishwater impoundments

3.3 CONCEPTS, DEFINITIONS AND TERMINOLOGIES

For the success of a collection methodology, it is essential to ensure that the data are accurately collected. This can only be possible when all the terms used in the study are clearly and unambiguously defined and the concepts involved in the survey are properly explained. For example, while surveying a water unit, it may be wrongly classified under other resource if proper definition for all the classes are not uniformly followed. Hence, to maintain the uniformity in data collection work, the following definitions of various resources would be broadly followed for simplicity.

Resource concepts and definitions

Ponds : Ponds are usually earthen, shallow, excavated water bodies, though masonry dykes are also not uncommon. Pond represents a restricted environment without a continual interaction with populations of neighbouring biotopes. The water level and biomass within are highly influenced by the rate of evaporation and precipitation. Inundation is often the lone factor leading to exchange of biological communities with adjacent water bodies.

For fisheries enumeration purposes, all such water bodies having an area of less than 5 ha at full water level are designated as ponds. Fish production from these ponds is estimated at 800-2000 kg ha^{-1} without application of fertilizers and supplementary feed, the productivity level being determined by the inherent nutrient status of soil and water, and to a great extent, the nutrient leaching from the surroundings. Scientific farming, however, has resulted in yield exceeding 10 tonnes per ha pond area per year.

Tanks : Tanks are generally referred, in common parlance, to denote varying types of water bodies in different parts of the country. Tanks are larger than ponds, created on seasonal streams, mainly for irrigation purposes by constructing earthen or masonry barricades. These shallow water bodies generally get dried up during summer. Large excavated community ponds or temple tanks also fall under this category. Tanks, on management, have a potential to yield 500-1000 kg or even up to 2000 kg under scientific fish farming. Many authors consider tanks as an interchangeable expression for ponds and small reservoirs and these resources are often clubbed in resource assessment. Water bodies having an average area of 5-10 ha, irrespective of their water source, may be considered as tanks. These include small irrigation impoundments, temple tanks, community tanks and natural tanks fed by catchment from neighbouring areas.

Lakes : All lentic water bodies of natural origin exceeding 10 ha in area are included under the category of lakes. The process leading to the formation of these natural lakes may very widely. Basins formed due to tectonic movements of earth crust, volcanic or glacial action, or wind action in the arid zones, depressions from landslides, or the basins formed due to stream action (flood plains) all constitute the natural lakes.

The upland lakes spread across the higher altitude regions of the country are mostly of volcanic, glacial or tactonic origin. These harbour a variety of coldwater fish species.

Floodplain lakes : These natural lakes constitute an impressive resource for fishery development in the country. Floodplain lakes generally are formed by the silt deposition, erosion or change in stream course. A meandering stream may erode the outside shores of its broad bend cutting off the loops forming an oxbow lake. This may retain the connection with the parent river (live beels) or in course of time may become a separate entity altogether (dead beels). Floodplain lakes cover extensive areas in the states of Eastern U.P., Northern Bihar, West Bengal, valley districts of Assam, Manipur, Tripura and foothills of Arunacsal Pradesh and Meghalaya and are commonly referred to as *beels, jheels, mans, chaurs, tals, pats* and *kols* depending on the states in which they are located. The lakes formed due to inundation of low-lying stretches during flood also contribute to the floodplain lakes. Floodplains widely vary in dimension from a few hectares to several hundred hectares. The total area under the floodplain is estimated at 2.0 lakh ha. The fish production potential of flood plains is worked out to be upto 1000 kg per ha annually.

Rivers : A river by definition, is a large body of flowing water constrained in a channel. All the small and large rivers, along with the major irrigation channels arising out of them, are considered under riverine resources for the sake of the fishery enumeration.

The riverine fishery resources of India are grouped under five major river systems, the Ganga, the Brahmaputra, the Indus, the East Coast and the West Coast system. The major river systems together exceed 29,000 km in length and along with the canal systems they are estimated to exceed 1,12,000 km.

The Ganga System having a combined length of 12,500 km comprises several rivers draining the southern slopes of Central Himalayas and covers Delhi, Haryana, Uttar Pradesh, Bihar, parts of Rajasthan, Madhya Pradesh and West Bengal.

The Brahmaputra system drains the northern slopes of Central and Eastern Himalayas, Assam, Bhutan, Sikkim and parts of West Bengal. Only a part of the Indus system traverses the Indian states, especially Punjab, Himachal Pradesh and Jammu and Kashmir. The East Coast System covers the entire peninsular India, east of Western ghats embracing the states of Orissa, Andhra Pradesh, parts of Madhya Pradesh, Karnataka and Tamil Nadu. The West Coast System includes the basins of Narmada and Tapti and the drainages of Gujarat apart from the narrow belt of peninsular India, west of Western Ghats.

The Riverine resources are not only important to the country in terms of fish yield, but also as the natural abode of the diverse and rich fish genetic wealth.

Conservation of fish germ plasm and optimisation of yield are two key factors directing policies of riverine fishery exploitation.

Reservoirs : Reservoirs are man-made impoundments of varying magnitude created by erecting bunds, dams, barrages or other hydraulic structures across streams or rivers, serving one or more purposes such as irrigation, power generation, flood control or other water resource development projects. All such water bodies, exceeding 10 ha in area at full level, are categorised as reservoirs. There are numerous lakes in the floodplains of peninsular rivers which draw from the catchment of the tibutaries that no longer contribute to the main river. The states of Maharashtra and Madhya Pradesh have many such lakes which are traditionally recorded as reservoirs. For the sake of uniformity, these lakes, if above 10 ha, are also considered as reservoirs.

A large number of river valley projects taken up since independence have resulted in a chain of artificial impoundments across the country. By their sheer magnitude, they form one of the main freshwater fishery resources of the country, now estimated at 5.18 lakh ha in area. Each reservoir is a separate ecological entity and varies from another in its morphometry, area, geographical location and productivity status. For convenience of adopting a fisheries management strategy and to obtain a reliable estimate of fish production from them, these are further classified into three groups based on their area at FRL:

1. Small reservoir (10-500 ha)
2. Medium reservoirs (500-1000 ha)
3. Large reservoirs (above 1000 ha)

Approach to fishery management in each class of these reservoirs depicts some basic differences. Small reservoirs permit a near total exploitation of the stock annually due to depletion of water level during summer. An annual stocking and cropping policy is adopted in them. Provision for fertilization is also not ruled out. In medium reservoirs too, stocking forms the mainstay in management. Natural productivity of the reservoir is more or less accurately estimated and stocking policy evolved. A production up to 300 kg per hectare is achievable from these water bodies at the present level of technology.

Large reservoirs, on the other hand, are managed to obtain a maximum sustainable yield on a long-term basis. Endemic fish fauna is generally the chief contributor to the yield. Stocking is aimed at rectifying population imbalances, if any, and to fill the vacant niches, based on natural food spectrum available in the water body. Stocking mainly supplements the natural recruitment. Observance of closed season and gear regulation are other chief management options in large reservoirs. Production level of 100 kg or more per hectare envisaged annually in well-managed large reservoirs.

Estuaries : An estuary is a semienclosed coastal body of water which has free connection with the sea and within which the seawater is measurably diluted by freshwater derived from land drainage. This ecotone is a buffer zone between freshwater of the drainage and saline water of the sea.

The river discharge interacts with the seawater and the river water and the seawater are mixed by the action of tidal motion, wind stress on the surface and the river discharge forcing its way into the sea. The salinity gradient in the estuary is determined by the quantum of water being discharged by the drainage, the velocity of the flow and the tidal force experienced at the river mouth. Salinity pattern consequently is a good indicator of the estuarine mixing and pattern of water circulation in an estuary. The quality and quantity of the biotopes in an estuary directly dependent on this salinity gradient and the nature of estuarine bed.

Estuarine ecological environments are complex and highly variable. They are richly productive. Nevertheless, because of the constant variability, only few species having wider tolerability to variations exist as permanent residents of the estuary. A number of marine forms are indigenous to the estuary, and the environment serves as a nursery ground for many other species. The migratory finfish and shell fish varieties also require a conducive estuary to contribute substantially to the estuarine fishery.

Estuary associated coastal water bodies are essential components of the estuarine systems, often taking the shape of lagoons, creeks, backwaters and so on. These are directly or indirectly connected and influenced by the tidal action. Salinity pattern in coastal lagoons and backwaters is decisively dependant on the precipitation rate and the tidal influx. The lagoons are usually shallow and the secondary production is often concentrated in the sediments (with its short benthic food chains) rather than in the water column. Estuaries and associated impoundments have considerable impact on the adjacent marine fisheries because they serve as the nursery areas for many fish and shellfish that move out to sea in later life.

The estuarine fisheries resource of India comprise mainly of the Hooghly-Matlah, the Mahanadi, the Godavary and the Narmada system along with the tidal creeks and mangroves of Sunderbans, the coastal lagoons like chilka and Pulicat lakes and the chain of backwaters of Kerala. The entire area under this class is estimated at about 2.6 million hectares giving fish yield between 4.7 and 75 kg/ha.

Brackishwater impoundments : These are estuarine man-made impoundments where freshwater is mixed with sea water. Due to the tidal action, the beds of many rivers and creeks in the estuarine areas of Bengal gets silted up and in due course they are reclaimed for agricultural purposes by constructing bunds to safeguard against floods and tidal water. Some portion of these reclaimed areas are too low for agricultural crop cultivation and are utilised for fish culture. They support both finfish and shellfish fisheries. The brackishwater tidal wetland namely mud flats, swamps, marshes, paddy fields, etc. are locally known as "bheries" in West Bengal. They are large shallow water bodies embanked by low earthen dykes all around and are located in the north, north-east and south of the Sundarbans in the district of 24-Parganas of West Bengal. An inventory survey during 1982-84 has estimated the total number of bheries as 1334 covering a brackishwater area of about 0.033 lakh ha spread over three saline zones *viz.*, high, medium and low. The shape of bheries is irregular and the size varies from a small (2 ha) to big water area (267 ha).

Swamps may be defined as derelict marshy water bodies mostly infested with grasses and weeds. They are seasonal in character and vary widely in water depth and area.

3.4 SAMPLING CONCEPTS :

The material described below is intended to provide brief introduction to some sampling concepts, terminologies and to suggest some specific sampling methodologies with examples which are believed to be specially useful to fishery scientists interested in estimating the catch from various fisheries. This material is necessarily brief and a limited familiarity with basic statistics is assumed. The interested reader may refer to the important contributions to sampling described in text books (Cochran, 1977; Sukhatme and Sukhatme, 1970) for further background and detail.

The basic motive of any sampling scheme is to minimize sampling error for a given cost, or to minimize cost for a given allowable sampling error. The selection in either case depends on the particular problem under study and the amount of prior information available. Some basic sampling methods available for use include stratification, clustering, sub-sampling, systematic sampling etc. This material will cover only a few of the available sampling methods considered in our studies.

Some Basic Sampling Concepts

A sample survey is a vehicle for inductive reasoning. It provides for the transformation of observations of a part into conclusion regarding the whole. Taking samples is a procedure used in nearly all fisheries investigations and from the sample taken we intend to generalise about the population under investigation. For example, taking a sample of catch from a vessel operated in a water body, we want to say something about the total catch of fish from it. If we are to do a job like this, then our sample must be taken carefully which may enable us to use standard statistical tools for the purpose.

Firstly, we must define what we mean by a population. Population is an aggregate of individuals having some characters in common. In the example just described, the vessels will constitute a population of vessels having water body as common character. Secondly, sample is a part of population where individuals are selected with some pre-assigned probability.

The efficiency of any sampling scheme is its amenability to a satisfactory generalization about the population from the sample or samples.

Basic Sampling Techniques :

These techniques include:

(i) Simple Random Sampling

(ii) Stratified Sampling

(iii) Cluster Sampling

(iv) Systematic Sampling

(v) Two-stage Sampling.

In material which follows, the formulae for estimation of population means and variances are provided in Appendix-3 rather than being included in the description of the basic designs. The reasons for doing this are to make easier reading for those interested only in the general rationale behind the design, as well as providing all computational formulae together for ease of comparison.

Simple Random Sampling

In simple sampling, all units have equal probability of being selected in the sample and every possible sample of required size has the same chance of selection. The units in the population are numbered 1 to N, the sample (n) is drawn either by Lottery Method or by Random Number Table as described in most statistics books.

Stratified Sampling

In stratified random sampling, the population is divided into non-overlapping sub-populations called strata. A sample is then drawn from each stratum. There are four prime reasons for stratification.

(i) It ensures adequate representation to various sub-divisions of the population.

(ii) It may be logically or administratively convenient to break up the population into strata for better organization and supervision of field work.

(iii) Sampling problems may differ in different parts of the population.

(iv) Finally, and most importantly, considerable precision may be gained by dividing a heterogeneous population into homogeneous strata. Differences between strata do not contribute to the stratified sampling variance. Therefore, the smaller the variability within strata, the smaller the sampling variance.

The simplest way to allocate the sample is to use proportional allocation. Once the overall sample size is arrived at, one makes the no. of sample units drawn from each stratum proportional to the total number of units in that stratum, i.e., for the i-th stratum

$$n_i = N_i \, n/N$$

Where n_i and N_i are sample and population size of i^{th} strata and N and n are the sizes of entire population and sample.

Proportional allocation overlooks two items of information that may sometimes be available to the fishery scientists. These are :

(i) differences in variance (S_i^2) from stratum to stratum, and

(ii) differences in the cost (C_i) associated with observing a unit in each stratum.

The purpose of sampling is to minimise both sampling variance and cost. Therefore, it follows that more units should be drawn from high variance strata where sampling is inexpensive. When the stratum sample size (n_i.) is directly proportional to respective standard deviation (S_i.) and inversely proportional to the square root of cost, allocation is then called optimum allocation. If the fishery scientist is confident in his estimate of at least the relative magnitude of C_i, optimum allocation is suggested in stratified sampling, and sample size is determined by

$$n_i = n \, N_i \, S_i \, / \, \Sigma \, N_i \, S_i$$

Here, strata variances are obtained from previous survey or pilot survey. Variance can be estimated as:

$$V(\bar{y}) = \frac{1}{n} (\Sigma \, W_i S_i)^2 - \frac{1}{N} \Sigma \, W_i S_i^2, \text{ where } W_i = N_i/N$$

Cluster Sampling

In cluster sampling the population is divided into groups or clusters of units. Several of the clusters are chosen at random and all units in each selected cluster become part of the sample. The clusters are often referred to as primaries and the units contained therein are called secondaries.

Choice of cluster sampling in fish catch surveys is of immense use due to the two major advantages of this sampling.

(1) Sometimes there is no sampling frame available to base a sample selection, and it is that such a list would be expensive to obtain, whereas it is relatively easy to obtain a list of clusters of units. For example, it is desired to sample the villages bearing ponds and tanks, the list of which is difficult to obtain unless large resources and manpower are devoted for the same.

(2) Cluster sampling may also be desirable if the population is such that sampling costs (travel, time) may be reduced by selecting adjacent units. For example, it may be cheaper to select some villages and sample good proportion of ponds and tanks or fishing units rather than to take a simple random sample of ponds or fishing units, in area of interest.

If, in estimating area, a choice is made between several cluster sizes, it can be shown that the criteria is to choose that cluster size that minimises the product of sample variance and total cost (both of which vary depending upon cluster size).

Two-stage Sampling

In the cluster sampling all the units of the selected clusters are measured completely. If the elements within a cluster give similar results, it seems uneconomical to measure them all. A common practice is first to select clusters, called primary units and then choosing units called second stage units or secondary units from the clusters. This is known as two-stage sampling. For example in estimating the yield of fish in a district, villages may be considered as primary sampling units, the ponds within villages as second stage units.

Systematic Sampling

In the sampling designs so far discussed, the successive units are selected at random. Whereas in systematic sampling only the first unit is selected at random, the rest being selected automatically according to a predetermined pattern.

Suppose that the N-units in the population are numbered 1 to N in some order. To select a sample of n units, we take a unit at random from the first k units and every k^{th} unit thereafter. The selection of first unit determines the whole sample. This type is called every k-th systematic sample. The selection of every k^{th} time interval for observing the number of fishing craft landing at a centre is an example of systematic sampling. The method is extensively used on account of its low cost and simplicity in the selection of the sample.

3.5 COLLECTION OF CATCH AND FISHING EFFORT DETAILS

The collection of catch and fishing effort data is not easy. Even when the law makes it obligatory for a fisherman to give information, he will not necessarily give the correct information if he knows there is no way of checking, resulting increased dependence on him. So, it is worthwhile to befriend him. Tell him why you want the information. Listen with interest to his answer and be prepared to listen to his trouble as well. If there are laws governing the fishery, for example, minimum mesh size regulations or minimum legal landing size, try to make sure that you are not the person who has to enforce the laws.

3.6 POPULATION AND CHOICE OF SAMPLING UNIT

In any sampling problem it is essential to define the population and an appropriate sampling unit. For our purpose it is always the easiest to consider where the fish are landed or first become available for weighing or recording, rather than the position where the actual fishing takes place. Obviously the fishery may be based on a number of distinct landing places each of which can be considered as a unit. In a more complex situation such as coast line or a river, the natural unit is a certain length of river or coast line. The size of the unit should be best taken sufficiently small for one man to cover preferably in a day. Some of the primitive fishing takes place all over an area, e.g. in swamps or irrigation channels, the fish either being consumed locally or sent to market in small lots. Here the unit may be an area of ground.

The first step would be to achieve some stratification, dividing the units (landing places, stretches of coast) according to the order of magnitudes of their fisheries.This needs some preliminary survey of the fishery, and, for the fisheries without definite landing places, possibly some geographical survey to delimit precisely the boundaries of the units. Where the division between units may be drawn rather arbitrarily on a stretch of fairly uniform coast, it is best to draw the divisions to make the catches in units of the same class as equal as possible.

3.7 THE COLLECTION OF CATCH DATA

There are many ways of collecting information on catch. Obviously, totally different system must be adopted to meet widely differing conditions and fishery resources. The number of staff available to undertake the work, and also their capability will also vary. Hence, the collection programme must be designed keeping in view the local conditions and circumstances.

In some cases this information is available from sale sheets listing weight and values by species maintained by arathdars, cooperative societies, government departments etc. In the absence of such cases, information has to be collected from the source.

(A) When there are well defined and identifiable centres having better infra-structural facilities for easy disposal of fish catch, then the required information may be collected by covering these centres, called landing centres.

(B) When such landing centres are difficult to locate and the fish catch normally passes to the consumer directly from the fishermen then the following procedure may be considered.

(i) Fishing communities bring their catch at isolated places along the entire stretch of water bodies (rivers, reservoirs, etc.) and these places may not be easily approachable and there is no fixed time for bringing their catch. In such cases the fishing parties who are easily identifiable may be approached to supply the information. This type of situation prevails in the upper stretch of the Hooghly estuary.

(ii) There are occasions where the catches are disposed through more than one channel, bulk of catches are taken to the convenient places, such as railway stations for transport of fishes to the market. Rest of the catches are disposed through hawkers, local markets and self consumption (subsistence fishery). In such cases complete information on bulk disposal can be obtained from the railway station. But the record available with the railway authority will give informaton only on total fish booked for the market. Information on prices and the percentage composition of species caught from the given water-body and the percentage disposed through hawkers, local market and subsistence fishery could be obtained by visiting the known landing sites by enquiry/physical observation.

Again, fish landings may be considered under two major heads. (1) Regular landings: From water bodies like reservoirs fish landings take place almost daily. Such types of landings may be considered as regular landings. (2) Other landings: Landings from tanks and seasonal water bodies, where water is available in certain seasons, are not regular. The method of approach to collect information from such waterbodies are given below:

Since there is no fixed period or time for fish landings from such water bodies, it is difficult to collect all information from them by direct observation. Hence, for these cases enquiries and direct observation approach is only solution to obtain catch estimate.

Suitable sampling designs meeting the requirements to regular as well as other landings are coming in the subsequent chapters.

CHAPTER—4

ESTIMATION OF RESOURCE AND CATCH FROM PONDS AND TANKS

Ponds and tanks contribute appreciably to the total inland fish production and the assessment of its contribution precisely is of utmost importance. The catch assessment procedure described below is expected to provide precise and reliable estimate of resource under this class and its fish production.

4.1 COVERAGE

For estimating the water resource and fish catch from ponds and tanks, a State may be divided into three agroclimatic zones for estimation purposes. The criteria for classification adopted here would be on the basis of high, moderate and low rainfall.

From the high rainfall region, a set of three districts will be selected at random for resource and catch estimation where two districts will be selected from moderate rainfall area and one district from low rainfall area in order to provide larger sample for high concentration of units and smaller sample for low concentration of water units. Here, it would be assumed that these sample districts would be representatives of the districts from which they are selected. However, it is advisable to launch the survey in all the districts of the State if enough manpower support and resources are available.

4.2 SAMPLING DESIGN

The sampling design for estimating the extent of culturable water area under ponds and tanks would be stratified two stage cluster sampling. A district is divided into three strata approximately of equal size in respect of water area/no. of villages. A sample of six clusters of five villages each will be selected from each stratum. Cluster of villages will constitute the first stage unit and the ponds within cluster as the second stage unit. Selected villages will be surveyed completely and all the water units in the village will be enumerated for estimating the average area under water units. However, the number and size of clusters may vary depending on the concentration of water units in the villages. An alternative approach may also be adopted for selection of villages by random sampling instead of cluster ones where the location of villages is such that it is not profitable to group them in clusters.

The sample may be selected by adopting the following procedure. List all the villages talukawise in a district. Now divide the talukas in 3 strata such that the number of villages in each stratum is approximately equal. From each stratum, select six villages called the key villages at random from the list of villages. Now list all the villages surrounding each of the key village and then select a random sample of 4 villages corresponding to each of the key village. In this way a sample of six clusters of five villages each in a stratum may be selected for resource estimation.

For estimating the total catch of fish, five ponds/tanks will be selected from each cluster at random from the total number of ponds in the cluster. In case the number of ponds in a cluster is less than 5, all shall be taken in the sample for observation of catch. Thus from each district a total of 90 villages will be selected for estimating the water area under ponds and tanks and 90 ponds for estimating the catch of fish. Further, sampling in time may also be adopted so that each water unit is visited at least once in a month depending on the availability of manpower for recording the catch from each pond more accurately and for providing the estimates of monthly catches also.

In cases where the villages around the key village do not have ponds or tanks the procedure to be adopted is given as under :

Divide the selected district into three approximately equal strata as indicated above and select a simple random sample of 20% villages bearing ponds and tanks for estimation of water area and 5 ponds in each village for estimation of fish catch statistics. In the situation where number of ponds is less than the desired number, then all the ponds may be included in the sample of collection of data. For both of these methods, the canvassing schedule no. 1.1 may be utilised for collection of data.

4.3 ORGANIZATION OF FIELD WORK

Each district may be assigned to three field enumerators trained in collection of data who should be given the responsibility of physically surveying the selected cluster of villages in the district under supervisory officers at the district headquarters. In the first round of survey, data on all the tanks and ponds in the selected villages will be recorded together with other required information and then in the second round the selected ponds and tanks in each cluster of villages will be surveyed regularly once in a month for catch estimation purpose. In the proposed plan, each district has 18 clusters of 5 villages each. It is, therefore, expected that the first round will be completed within a month's time and the second round will immediately follow after the selection of sample water-bodies.

4.4 TYPE OF DATA TO BE COLLECTED

In the first round, for resource survey part, the data would be collected comprising water area, seasonality, depth, soil type, utilization of water units, cultural practices, species cultured, total fish production etc., in the prescribed proforma (Proforma no. 1.1). In the second round, each selected pond in the cluster will be observed once in a month for record of fish yield and the catch will be recorded in the proforma no. 2.1.

4.5 ESTIMATION PROCEDURE

Notations :

N_h = Total number of clusters in h-th stratum. ($h = 1, 2, 3, \ldots\ldots\ldots, L$)

n_h = No. of sample clusters in h-th stratum.

v = No. of villages in a cluster.

M_{hij} = No. of ponds in j-th village of i-th cluster in h-th stratum.
($i = 1, 2, \ldots\ldots\ldots n_h$; $j = 1, 2, \ldots\ldots\ldots, v$)

M_{hi} = No. of ponds in i-th cluster of h-th stratum.

$$M_{hi} = \sum_{j=1}^{v} M_{hij}$$

m_{hij} = No. of ponds selected from j-th village of i-th cluster in h-th stratum.

m_{hi} = No. of ponds selected from i-th cluster of h-th stratum.

$$m_{hi} = \sum_{j=1}^{v} m_{hij}$$

X_{hijk} = Area of k-th selected pond in j-th village of i-th selected cluster of h-th stratum.

($i = 1, 2, \ldots\ldots\ldots\ldots, n_h$; $j = 1, 2, \ldots\ldots\ldots\ldots, v$;
$k = 1, 2, \ldots\ldots\ldots\ldots, m_{hi}$; $h = 1, 2, \ldots\ldots\ldots\ldots, L$)

Y_{hik} = Yield of k-th selected pond in i-th cluster of h-th stratum.
($k = 1, 2, \ldots\ldots\ldots m_{hi}$; $i = 1, 2, \ldots\ldots\ldots n_h$; $h = 1, 2, \ldots\ldots\ldots L$)

$\bar{M}_{hi}$ = Average no. of ponds in i-th cluster of h-th stratum.

$\hat{Y}$ = Estimate of total yield in the district.

$\hat{\bar{Y}}_h$ = Estimate of average yield per cluster in h-th stratum.

$\hat{\bar{Y}}'_h$ = Estimate of average yield per hectare per year in h-th stratum.

$\hat{\bar{Y}}'$ = Estimate of average yield per hectare in a district.

$\hat{X}_h$ = Estimate of average area per village in h-th stratum.

$\hat{X}$ = Estimate of total area in a district.

$\hat{\bar{M}}_h$ = Estimate of average no. of ponds per village in h-th stratum.

$\bar{X}_{hi}$ = Averege area per village in i-th cluster of h-th stratum.

$\bar{A}_{hi}$ = Average area of pond in i-th cluster of h-th stratum.

$\hat{\bar{A}}_h$ = Estimate of average area of pond in h-th stratum.

$\hat{\bar{A}}$ = Estimate of average area of pond in a district.

$\hat{M}$ = Estimate of total ponds in a district.

Estimators of number of ponds :—

Average no. of ponds per village in the h-th stratum is ;

$$\hat{\bar{M}}_h = \frac{1}{n_h} \sum_{i=1}^{n_h} \bar{M}_{hi}, \quad \text{where} \quad \bar{M}_{hi} = \frac{1}{v} \sum_{j=1}^{v} M_{hij}$$

Total no. of ponds in the district is ;

$$\hat{M} = \Sigma\, N_h.\, v.\, \hat{\bar{M}}_h \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Estimators of Area on village basis :—

Average area per village in h-th stratum is ;

$$\hat{\bar{X}}_h = \frac{1}{n_h} \Sigma\, \bar{X}_{hi}, \quad \text{where} \quad \bar{X}_{hi} = \frac{1}{v} \sum_{j=1}^{v} \sum_{k=1}^{M_{hij}} X_{hijk}$$

Average area per village in the district :—

$$\hat{\bar{X}} = \frac{\Sigma\, N_h\, \hat{\bar{X}}_h}{\Sigma\, N_h} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Total area in the district is :

$$\hat{X} = \Sigma\, N_h.\, v.\, \hat{\bar{X}}_h \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Estimate of variance of total area in the district is

$$\hat{V}(\hat{X}) = \Sigma\, v^2 N_h^2 (1/n_h - 1/N_h) \{1/(n_h - 1)\} \Sigma(\bar{X}_{hi} - \hat{\bar{X}}_h)^2$$

Estimators of area on pond basis :—

Estimate of average area per pond in h-th stratum is ;

$$\hat{\bar{A}}_h = \frac{1}{n_h} \Sigma \bar{A}_{hi}, \qquad \bar{A}_{hi} = \frac{1}{v} \Sigma \frac{X_{hij}}{M'_{hij}}, X_{hij} = \sum_k X_{hijk}$$

Average area per pond in the district is ;

$$\hat{\bar{A}} = \frac{\Sigma N_h \hat{\bar{A}}_h}{\Sigma N_h} \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots (4)$$

$$\hat{V} (\hat{\bar{A}}_h) = \left(\frac{1}{n_h} - \frac{1}{N_h} \right) \frac{1}{n_h - 1} \Sigma (\bar{A}_{hi} - \hat{\bar{A}}_h)^2$$

$$\hat{V} (\hat{\bar{A}}) = \frac{1}{(\Sigma N_h)^2} \Sigma \{ N_h^2 \left(\frac{1}{n_h} - \frac{1}{N_h} \right) \frac{1}{n_h - 1} \Sigma (\bar{A}_{hi} - \hat{\bar{A}}_h)^2 \}$$

Estimators of Yield :—

Average yield per cluster in h-th stratum is ;

$$\hat{\bar{Y}}_h = \frac{1}{n_h} \Sigma M_{hi} \bar{Y}_{hi}, \quad \text{where } \hat{\bar{Y}}_{hi} = \frac{1}{m_{hi}} \Sigma Y_{hik}$$

Total yield in the district,

$$\hat{Y} = \Sigma N_h \hat{Y}_h \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots (5)$$

Estimate of variance of total yield in the district ;

$$\hat{V}(\hat{Y}) = \Sigma \{ N_h^2 (1/n_h - 1/N_h) s^2_{bh} + (N_h/n_h) \Sigma M_{hi}^2 (1/m_{hi} - 1/M_{hi}) s_{whi}^2 \}$$

where $s_{bh}^2 = \frac{1}{n_h - 1} \Sigma \{ M_{hi} \bar{Y}_{hi} - \frac{1}{n_h} \Sigma M_{hi} \hat{\bar{Y}}_{hi} \}^2$

and $s_{whi}^2 = \frac{1}{m_{hi} - 1} \Sigma (Y_{hik} - \hat{\bar{Y}}_{hi})^2$

Estimator based on yield per hectare in h-th stratum ;

$$\hat{\bar{Y}}'_h = \frac{1}{n_h} \Sigma \hat{\bar{Y}}'_{hi} \quad \text{where } \hat{\bar{Y}}'_{hi} = \frac{1}{m_{hi}} \Sigma \frac{Y_{hik}}{X_{hik}}$$

Average yield per hectare in a district is ;

$$\hat{\bar{Y}}' = \frac{\Sigma N_h \hat{\bar{Y}}'_h}{\Sigma N_h}$$

Estimated variance of $\hat{\bar{Y}}'$ is given by ;

$$\hat{V}\left(\hat{\bar{Y}}'\right) = \frac{1}{(\Sigma N_h)^2} \Sigma N_h^2 \left\{ \left(\frac{1}{n_h} - \frac{1}{N_h}\right) s_{bh}^2 + \frac{1}{n_h N_h} \Sigma \left(\frac{1}{m_{hi}} - \frac{1}{M_{hi}}\right) s_{whi}^2 \right\}$$

where $s_{bh}^2 = \frac{1}{n_h - 1} \Sigma \left(\hat{\bar{Y}}'_{hi} - \hat{\bar{Y}}'_h\right)^2$

and $s_{whi}^2 = \frac{1}{m_{hi} - 1} \Sigma \left(\frac{Y_{hik}}{X_{hik}} - \hat{\bar{Y}}'_{hi}\right)^2$

Example 1 : The data given below relate to three clusters of stratum-I in the district of Midnapore, West Bengal for estimating the total area under ponds and tanks. The total no. of clusters in the stratum is 349. The sampling methodology is stratified cluster sampling.

Cluster	Sl. No. of Village	No. of Ponds	Total Area
1	1	1	0.12
	2	8	2.39
	3	10	6.18
	4	5	1.87
	5	4	1.10
2	1	1	0.55
	2	8	1.61
	3	4	0.91
	4	17	4.03
	5	1	0.32
3	1	5	1.30
	2	1	0.10
	3	1	0.75
	4	16	3.13
	5	0	0.00

Per Village Basis (For stratum-I)

Average area per village in stratum $1 = \hat{\bar{X}}_1$

$= \frac{1}{n_1} \Sigma \bar{X}_{1i}$, where $\bar{X}_{1i}$ is the average area per village in the i-th cluster.

$= 1/3 \times [\{ (0.12 + 2.39 + 6.18 + 1.87 + 1.10)/5 \} +$
$\{ (0.55 + 1.61 + 0.91 + 4.03 + 0.32)/5 \} +$
$\{ (1.30 + 0.10 + 0.75 + 3.13 + 0.00)/5 \}]$

$= \frac{1}{3} \{ (11.66 / 5) + (7.42 / 5) + (5.28 / 5) \}$

$= \frac{1}{3} (2.332 + 1.484 + 1.056) = \frac{1}{3} \times 4.872 = 1.624$

Total area in the stratum $= 5N_1 \hat{\bar{X}}_1 = 5 \times 349 \times 1.624$
$= 2833.88$ ha.

Estimated variance of $\hat{\bar{X}}_1 = \hat{V} (\hat{\bar{X}}_1)$

$= \left(\frac{1}{n_1} - \frac{1}{N_1}\right) \frac{1}{n_1 - 1} \Sigma (\bar{X}_{1i} - \hat{\bar{X}}_1)^2$

$= \left(\frac{1}{3} - \frac{1}{349}\right) \times \frac{1}{3-1} \left(2.332^2 + 1.484^2 + 1.056^2 - \frac{4.872^2}{3}\right)$
$= 0.139372$

Average no. of ponds per village in stratum 1 $= \hat{\bar{M}}_1$

$= \frac{1}{n_1} \Sigma \bar{M}_{1i}$, $\bar{M}_{1i}$ is average no. of ponds / village in the i-th cluster.

$= \frac{1}{3} \{ (1+8+10+5+4)/5 + (1+8+4+17+1)/5 + (5+1+1+16+0)/5 \}$

$= 5.47$

Per Pond Basis

We prepare the following table.

Stratum	Cluster	Sl. No. of Village	Av. area per pond
1	1	1	0.1200
		2	0.2987
		3	0.6180
		4	0.3740
		5	0.2750
	2	1	0.5500
		2	0.2012
		3	0.2275
		4	0.2370
		5	0.3200
	3	1	0.2600
		2	0.1000
		3	0.7500
		4	0.1956
		5	0.0000

Estimate of the area per pond

$= \hat{\bar{A}}_1 = \frac{1}{N_1} \Sigma \hat{\bar{A}}_{1i}$, $\hat{\bar{A}}_{1i}$ is average area of pond in i-th cluster.

$$=1/3 \times [\ (.1200+.2987+.6180+.3740+.2750)/5\ + \\ (.5500+.2012+.2275+.2370+.3200)/5\ + \\ (.2600+.1000+.7500+.1956+.0000)/5\ ]$$

$$= \frac{1}{3}(.3371+.3071+.2611) = .3018$$

Estimated variance of $\hat{\bar{A}}_1 = \hat{V}(\hat{\bar{A}}_1)$

$$= \left(\frac{1}{n_1} - \frac{1}{N_1}\right) \frac{1}{n_1 - 1} \Sigma(\hat{A}_1 - \hat{\bar{A}}_1)^2$$

$$= \left(\frac{1}{3} - \frac{1}{349}\right) \times \frac{1}{3-1}(.3371^2 + .3071^2 + .2611^2 - 3 \times .3018^2)$$

$$= .00048424$$

Example 2 : The following data relate to the estimate of area and variance in four strata of Midnapore district in the state of West Bengal for estimating the total area under ponds and tanks.

(a) Per Village Basis

Stratum	N_h	n_h	$(\hat{\bar{X}}_h)$	$\hat{V}(\hat{\bar{X}}_h)$
1	349	3	1.6240	0.13937233
2	751	3	0.7045	0.01505555
3	620	3	6.4499	6.56001396
4	634	3	10.5016	26.61673234

(b) Per Water Unit Basis

Stratum	N_h	n_h	$\hat{\bar{A}}_h$	$\hat{V}(\hat{\bar{A}}_h)$	$\hat{\bar{M}}_h$ (no. of ponds/ village)
I	349	3	.3018	.00048424	5.47
II	751	3	.1217	.00105333	6.33
III	620	3	.2077	.00917561	46.93
IV	634	3	.1261	.00134386	98.67

Solution :

(1) Per Village Basis

Total Area, $\hat{X} = \Sigma 5 N_h \hat{\bar{X}}_h = 5(349 \times 1.6240 + 751 \times 0.7045 + 620 \times 6.4499 + 634 \times 10.5016) = 58764.03$

Estimated variance of $\hat{X} = \hat{V}(\hat{X}) = \Sigma[5^2 \; N_h^2 \; \hat{V}(\hat{\bar{X}}_h)]$

$= 5^2 \; (349^2 \times .13937233 + 751^2 \times .01505555 + 620^2 \times 6.56001396 + 634^2 \times 28.61673234) = 331147291.62$

$$C.V. = \frac{\sqrt{331147291.62}}{5876403} \times 100 = 30.96 \; (\%)$$

(2) Per Pond Basis

Total no. of ponds $= \hat{M} = \Sigma \; 5 \; N_h \hat{\bar{M}}_h$

$= 5(349 \times 5.47 + 751 \times 6.33 + 620 \times 46.93 + 634 \times 98.67) \; = \; 491581$

Average area per pond $= \hat{\bar{A}} = \dfrac{\Sigma N_h \hat{\bar{A}}_h}{\Sigma N_h}$

$$= \frac{349 \times .3018 + 751 \times .1217 + 620 \times .2077 + 634 \times .1268}{349 + 758 + 620 + 634}$$

$= .1722$

$$V(\hat{\bar{A}}) = \frac{1}{N^2} \; \Sigma \; N_h^2 \; \hat{V}(\hat{\bar{A}}_h)$$

$$= \frac{1}{2354^2} \; (349^2 \times {\cdot}00048424 + 751^2 \times {\cdot}00105333 + 620^2 \times {\cdot}00917561 + 634^2 \times {\cdot}0013486)$$

$= {\cdot}00085184$

$$C.\;V. = \frac{\sqrt{{\cdot}00085184}}{{\cdot}1722} \times 100$$

$= 16{\cdot}95 \;\; (\%)$

Total Area $=$ No. of ponds $\times$ Average area per pond

$= 491581 \times {\cdot}1722$

$= 84650{\cdot}25$ (ha.)

Example 3 : The data given below are from one stratum of the district of Midnapore in West Bengal for estimating the catch. The total no. of clusters in the stratum is 349. The sampling procedure is two stage stratified cluster sampling.

Stratum	Cl	Catch records & area of ponds in bracket				
1	1	375.0 (1.004)	135.5 (0.132)	13.5 (0.096)	18.5 (0.048)	40.0 (0.168)
		20.0 (0.132)	114.0 (0.168)	7.0 (0.096)	56.0 (0.032)	111.0 (0.176)
		88.0 (0.148)	43.0 (0.080)	50.0 (0.168)	0.0 (1.940)	105.0 (0.212)
		600.0 (2.000)	0.0 (0.012)	(60.0 (0 040)	0.0 (0.160)	33.0 (0.036)
	2	12	Ponds			
	3	13	Ponds			

Solution For Stratum-I

Per Pond Basis

Total catch for 20 ponds in cluster—1 $= \Sigma\, y_{11k}$

$= 375{\cdot}0 + 135{\cdot}5 + \ldots\ldots\ \ldots\ldots\ \ldots\ldots\ldots + 33{\cdot}0 = 1869{\cdot}5$

Average catch / pond in cluster—1 $= \bar{y}_{11} = \dfrac{\Sigma\, y_{11k}}{m_{11}}$

$= 1869{\cdot}5 \,/\, 20 = 93{\cdot}47$

Average catch / pond in cluster—2 $= 1189{\cdot}5 \,/\, 13 = 91{\cdot}50$

Average catch / pond in cluster—3 $= 1729{\cdot}0 \,/\, 12 = 144{\cdot}48$

$$s_{w11}^2 = \frac{1}{m_{11}-1} \quad \Sigma\,(y_{11k} - \bar{y}_{11})^2$$

$$= \frac{1}{20-1} \left(375{\cdot}0^2 + 135{\cdot}5^2 + \ldots\ldots\ldots + 33{\cdot}0^2 - \frac{1869{\cdot}5^2}{20} \right)$$

$= 21214{\cdot}06$

$s_{w12}^2 = 17869{\cdot}54, \qquad s_{w13}^2 = 15802{\cdot}81$

Cl	M_{1i}	m_{1i}	$\hat{\bar{Y}}_{1i}$	s_{wi}^1	$M_1 \hat{\bar{Y}}_{1i}$
1	28	20	93.47	21214.06	2617.3
2	31	13	91.50	17869.54	2836.5
3	23	12	144.08	15802.81	3313.9

Average catch per cluster $= \hat{\bar{Y}}_1 = \frac{1}{3}(2617{\cdot}3 + 2836{\cdot}6 + 3313{\cdot}9)$

$$= 8767{\cdot}7 \;/\; 3 = 2922{\cdot}57$$

Total catch in stratum—I $= \hat{Y}_1 = N_1 \hat{\bar{Y}}_1$

$$= 349 \times 2922{\cdot}57 = 1019976{\cdot}93$$

$$s_{b1}^2 = \frac{1}{n_1 - 1} \quad \Sigma \left\{ M_{1i} \; \hat{\bar{Y}}_{1i} - \frac{(\Sigma \; M_{1i} \; \hat{\bar{Y}}_{1i})}{n_1} \right\}^2$$

$$= \frac{1}{3-1} \left(2617{\cdot}3^2 + 2826{\cdot}5^2 + 3313{\cdot}9^2 - \frac{8767{\cdot}7^2}{3} \right) = 12688{\cdot}49$$

Estimated variance of $\hat{Y}_1$,

$$\hat{V}\,(\hat{\bar{Y}}_1) = N_1^{\;2} \left(\frac{1}{n_1} - \frac{1}{N_1} \right) s_{b1}^2 + \frac{N_1}{n_1} \;\; \Sigma \; M_{1i}^{\;2} \left(\frac{1}{m_{1i}} - \frac{1}{M_{1i}} \right) s_{w1i}^{\;2}$$

$$= 349^2 \left(\frac{1}{3} - \frac{1}{349} \right) \times 126868{\cdot}49 + \frac{349}{3} \Big[\; 28^2 \left(\frac{1}{20} - \frac{1}{28} \right)$$

$$\times 21214{\cdot}06 + 31^2 \left(\frac{1}{13} - \frac{1}{31} \right) \times 17869{\cdot}54$$

$$+ 23^2 \left(\frac{1}{12} - \frac{1}{23} \right) \times 15802{\cdot}81 \Big] = 5262255336{\cdot}81$$

Yield Per Hectare

First the yield / hectare for each pond is calculated.

$$\frac{375{\cdot}0}{1{\cdot}004} = 373{\cdot}5, \quad \frac{135{\cdot}5}{0{\cdot}132} = 1026{\cdot}5, \ldots\ldots\ldots, \quad \frac{33{\cdot}0}{0{\cdot}036} = 916{\cdot}67$$

Average yield per hectare for cluster—1

$$\bar{y}'_{11} = \hat{\bar{Y}}'_{11} = \frac{373{\cdot}5 + 1026{\cdot}5 + \ldots\ldots\ldots\ldots\ldots\ldots + 916{\cdot}7}{20} = 499{\cdot}04$$

Average yield for cluster—2

$$\bar{y}'_{12} = \hat{\bar{Y}}'_{12} = 720{\cdot}65$$

Average yield for cluster—3

$$\bar{y}'_{13} = \hat{\bar{Y}}'_{13} = 1151{\cdot}39$$

Average yield / hectare in stratum—I

$$= \hat{\bar{\bar{Y}}}'_{1} = \frac{1}{n_1} \Sigma \hat{\bar{Y}}'_{1i}$$

$$= \frac{499{\cdot}04 + 720{\cdot}05 + 1151{\cdot}39}{3} = 790{\cdot}36$$

$$s_{11}^2 = \frac{1}{m_{11} - 1} \Sigma \left(\frac{y_{11k}}{x_{11k}} - \bar{y}'_{11} \right)^2$$

$$= \frac{1}{20-1} \left(373{\cdot}5^2 + 1026{\cdot}5^2 + 1026{\cdot}5^2 \ldots\ldots\ldots + 916{\cdot}67^2 - \frac{9980{\cdot}8^2}{20} \right)$$

$$= 231967{\cdot}66$$

$s_{12}^2 = 1381242{\cdot}52$,

$s_{13}^2 = 364278{\cdot}29$

Cluster	M_{1i}	m_{1i}	$\hat{\bar{Y}}'_{11}$	s_{11}^2
1	28	20	499.04	231967.66
2	31	13	720.65	1381242.52
3	23	12	1151.39	364278.29

$$s_{b1}^2 = \frac{1}{n_1 - 1} \Sigma \left(\hat{\bar{Y}}'_{1i} - \hat{\bar{\bar{Y}}}'_{1} \right)^2$$

$$= \frac{1}{3-1} \left(499.04^2 + 720.65^2 + 1151{\cdot}39^2 - \frac{2371.08^2}{3} \right)$$

$$= 110034.74$$

$$\hat{V} \left(\hat{\bar{\bar{Y}}}'_{1} \right) = \left(\frac{1}{n_1} - \frac{1}{N_1} \right) s_{b1}^2 + \frac{1}{n_1 \; N_1} \Sigma \left(\frac{1}{m_{1i}} - \frac{1}{M_{1i}} \right) s_{1i}^2$$

$$= \left(\frac{1}{3} - \frac{1}{349} \right) \times 110034.74 + \frac{1}{3 \times 349} \left[\left(\frac{1}{20} - \frac{1}{28} \right) \times \right.$$

$$\left. 231967.66 + \left(\frac{1}{13} - \frac{1}{31} \right) \times 1381242.52 + \left(\frac{1}{12} - \frac{1}{23} \right) \times 364278.29 \right]$$

$$= 36438.91$$

Example 4 : The data given below have been taken from the district of Aurangabad in the state of Maharashtra for 56 villages selected randomly out of estimated 285 villages having waterbodies less than 20 ha. for estimating the area under ponds and tanks.

Sl. No. of village	No. of ponds	Total area in the village (ha.)	Sl. No. of village	No. of ponds	Total area in the village (ha.)
1	1	17.0	29	2	16.0
2	1	4.0	30	1	2.0
3	2	13.0	31	1	10.0
4	1	6.0	32	1	10.0
5	1	13.0	33	1	9.0
6	2	17.0	34	1	6.6
7	1	17.0	35	1	16.0
8	1	7.0	36	1	16.0
9	1	8.0	37	1	10.0
10	1	16.0	38	1	18.0
11	1	7.0	39	1	13.0
12	1	14.0	40	1	17.0
13	2	34.0	41	1	12.0
14	1	13.0	42	1	10.0
15	1	11.0	43	1	15.0
16	2	18.7	44	1	11.0
17	1	16.0	45	1	13.0
18	1	16.0	46	1	14.0
19	1	17.0	47	1	12.0
20	1	8.0	48	1	10.0
21	2	14.0	49	1	20.0
22	1	5.1	50	1	18.0
23	2	19.0	51	1	20.0
24	1	8.0	52	2	13.0
25	1	15.0	53	1	5.0
26	2	15.0	54	3	14.0
27	1	12.4	55	1	14.0
28	1	16.6	56	1	19.0

Solution :—

Per Village Basis

Average area per village $= \hat{\bar{X}} = \frac{1}{n} \Sigma x_i = \frac{1}{56}$ (17.0 +

4.0 + ... + 19.0) = 13.24

Estimate of the Variance $\hat{V} (\hat{\bar{X}}) = \frac{N-n}{nN} \times \frac{1}{n-1} \Sigma (x_i - \hat{\bar{X}})^2$

$$= \frac{285 - 56}{56 \times 285} \times \frac{1}{56-1} \left(17.0^2 + 4.0^2 + ... + 19.0^2 - \frac{741.4^2}{56} \right) = .3888$$

$$\text{C. V.} = \frac{\sqrt{.3888}}{13.24} \times 100 = 4.71 (\%)$$

Total area in the district $= N \hat{\bar{X}} = 285 \times 13.24$
= 3773.4 (ha.)

Per Pond Basis

Average no. of ponds per village $= \hat{\bar{M}} = \frac{1}{n} \Sigma M_i$

$$= \frac{1}{56} (1 + 1 + 1 + ... + 1) = \frac{67}{56} = 1.1964$$

For average area per pond, the area per pond in each village is calculated :—

$$\frac{17.0}{1} = 17.0, \quad \frac{4.0}{1} = 4.0, \quad \frac{13.0}{2} = 6.5, \; ... \; ... \, , \quad \frac{19.0}{1} = 19.0$$

Average area per pond in the district $= \hat{\bar{A}}$

$$= \frac{1}{56} (17.0 + 4.0 + ... + 19.0) = 11.6468$$

Estimated Variance $\hat{V} (\hat{\bar{A}}) = \frac{285 - 56}{285 \times 56} \times \frac{1}{56-1}$ (17.0^2 +

4.0^2 + ... + $19.0^2 - 56 \times 11.6468^2$) = .3020

$$\text{C. V.} = \frac{\sqrt{.3020}}{11.6468} \times 100 = 4.72 \ (\%)$$

Total area in the district $= 285 \times 1.1964 \times 11.6468$
= 3971.25 (ha.)

Example 5: The following data relate to the catch record from eight villages from Kolhapur district in the state of Maharashtra for estimating the catch from waterbodies having area less than 20 ha. The total no. of villages having waterbodies less than 20 ha. is 269. The procedure followed is simple random sampling.

Village	Area of pond (in ha.)	Total Yield
Sonawadi	1.60	343.05
Sarud	3.20	832.85
Hatkonanjal	0.60	277.47
Talandaga	0.20	82.40
Mangalo	0.60	116.00
Kapileswar	0.15	40.00
Chuye	0.70	1603.65
Vadanga	12.27	1402.00

Per Village Basis

Average yield per village $= \hat{\bar{Y}} = \frac{1}{n} \Sigma y_i$

$= \frac{1}{8} (343.05+832.85+\ldots\ldots\ldots+1402.00) = \frac{4697.42}{8} = 587.18$ (Kg.)

Estimated variance $\hat{V}(\hat{\bar{Y}}) = \frac{N-n}{n.N} \times \frac{1}{n-1} \Sigma (y_i - \hat{\bar{Y}})^2$

$= \frac{269-8}{8 \times 269} \times \frac{1}{8-1} (343.05^2 + 832.85^2 + \ldots \ldots + 1402.00^2 - 8 \times 587.18^2)$

$= 46593.90$

C. V. $= \frac{\sqrt{46593.90}}{587.18} \times 100 = 36.76$ (%)

Total catch for the district $= 269 \times 587.18$ Kg.

$= 157.95$ tons

Per Hectare Basis

We calculate the yield / hectare and prepare the table.

$\frac{343.05}{1.60} = 214.41, \frac{832.85}{3.20} = 260.26, \ldots \ldots \ldots, \frac{1402.00}{12.27} = 114.26$

The average yield / hectare $= \hat{\bar{Y}}' = \frac{1}{n} \Sigma y'_i$

$$= \frac{1}{8}(214.41 + 260.26 + \ldots\ldots\ldots + 114.26) = \frac{4213.39}{8} = 526.67 \text{ (Kg.)}$$

Estimated Variance $\hat{V}(\hat{\bar{Y}}') = \frac{N-n}{n.N} \cdot \frac{1}{n-1} \Sigma (y'_i - \hat{\bar{Y}})^2$

$$= \frac{269-8}{8 \times 269} \cdot \frac{1}{8-1} \cdot (214.41^2 + 260.26^2 + \ldots \ldots + 114.26^2$$

$$- 8 \times 526.67^2) = 63134.19$$

$$\text{C. V.} = \frac{\sqrt{63134.19}}{526.67} \times 100 = 47.71 \ (\%)$$

CHAPTER—5

ESTIMATION OF FISH CATCH FROM RIVERS AND STREAMS

Rivers and streams constitute one of the important inland fishery resources in the country spreading over thousands of kilometers and passing through mountains, valleys, plains, ravines and other inaccessible areas.

5.1 COVERAGE

One or two important river systems in each of the State will be taken up initially in order to assess the fish production keeping in view the availability of manpower and facilities at the State level.

5.2 SAMPLING DESIGN

Capture fishery resources under rivers and streams sustain multigear and multispecies fishery exploited by artisanal fishermen operating on the entire area of the system making the estimation rather cumbersome. Most of the streams do not have well established landing centres where fishermen may land their catch. In some of the cases entire bank of the river acts as the landing point for them and they directly take the catch to the wholesale or retail market for final disposal. However, some rivers such as the Ganga have some landing centres at some points of stretch which can be considered for collection of data. Hence, we propose here two approaches for estimation of catch one considering fishing village as the sampling unit due to the absence of common landing points and the other considering landing centres as the sampling unit.

In the first approach, the stretch will be divided into suitable number of zones consisting of well defined fishing villages with more or less same type of craft and gear, fishing practices and species exploited. Here, fishing village is defined as a village having fishermen engaged in fishing activities in the body of water (river, in this case). The zones are completely enumerated for the total operating fishingunits. A sample of fishing villages will be taken to collect the information on catch and type of gear etc. to estimate the catch from the zone. The information is collected from the fishermen by both enquiry and physical observation. The investigator collects information on the total number of fishing units of the village fishing on that day, the total catch landed, the species composition by weight in respect of about 20% randomly selected units (with a minimum of 5) operating that day. He will also ascertain the number of fishing holidays by each type of fishing units since the last sampling day.

If complete enumeration of operating fishing units is not possible, than the double sampling is followed. From each zone a list of fishing villages will be prepared as a sampling frame and 20% (say, n') of the fishing villages will be selected with SRSWOR for estimating the total operating fishing units, craft, gear etc. and then a small sub-sample (say, n) of villages is selected with pps (no. of operating units) and with replacement. The character under study will be fish catch (y).

In the second approach, the entire stretch is divided into homogeneous zones of landing centres, each zone having more or less same type of gear and craft, fishing practices and species landed. From each zone a few landing centres are randomly selected depending on the manpower availability. A month is divided into three sets of ten consecutive days. From the first set two consecutive days are randomly selected where observations can be taken from the selected centre. From the second and third set of ten days each, clusters of two days are taken with a sample interval of ten days.

On the selected first day of observation in a centre, data are collected during 12.00 to 18.00 hrs and on second day during 06.00 to 12.00 hrs. Data on night landings, if any in between the the consecutive days, are collected by enquiry on the second day Thus in a two day cluster 24 hrs. observation is taken. This forms a landing centre day, the primary stage sampling unit. On the selected day of observation, if the number of units landed is 10 or less, then all the units are observed for gear-wise catches. When it exceeds ten a sample of units not less than ten is selected in a systematic way in predetermined manner depending on the total number of units landed during the period of observation (Alagaraja, 1984). Units landed form the second stage sampling unit from which data on specieswise catch, effort, type of craft and gear operated and nature of fishing ground are collected.

If formation of zones is not possible, then all the landing centres/landing points will be enlisted and grouped into high, moderate and low fish assembly centres. From each category a random sample of 20% of the landing centres will be selected for observation on fish catch. Further, sampling in time will also be adopted. For selection of days of observation, a month may be divided into three periods of ten days each. Two consecutive days may then be selected at random from the first 10 days of the month and the remaining sample days may then be chosen systematically at an interval of 10 days each. In this fashion, the sampling days for each selected landing centre/point will be then six in a month.

5.3 ORGANIZATION OF FIELD WORK

A field enumerator may be engaged in the collection of data in each zone and drawing of samples may be assigned to the statistician incharge at the State headquarters.

5.4 TYPE OF DATA TO BE COLLECTED

Data will be collected on all the crafts, gear, no. of operating fishermen with names of the head of family, area and season of operation etc. and will be recorded in the prescribed proformae (Schedule No. 1.4 (a) & 1.4 (b)) and the data on catch during sampling may be recorded in proforma no. 2.4.

5.5 ESTIMATION PROCEDURE

Although the capture fishery resources under rivers and streams sustain multi-gear and multi-species fishery exploited by artisanal fishermen operating on the entire area of the system making the estimation rather cumbersome but the method of approach followed as under will provide estimates depending on selection of ultimate unit at which data are collected.

(A) Fishing Village Approach :—

(i) When complete enumeration is possible.

To estimate the total monthly catch from the area under sample survey, first the total monthly catch by each type of gear in the sampled village is estimated. This will be :

$$\Sigma\ C_{ij}\ P_{ij}\quad T_{ij} = A_j$$

Where for j-th type of unit in i-th sampled village.

C_{ij} = Average catch per fishing unit per day.

P_{ij} = Average number of units operating per day.

T_{ij} = Number of fishing days in the month.

$C_{ij}\ P_{ij}$ = Average catch per day by j-th type of unit.

The total estimated catch for each zone is then :

$$\Sigma \frac{N_j}{n_j} \times A_j = B$$

Where N_j and n_j are the total number of operative gear of type j in the entire zone and in the seleted village respectively.

(ii) When compltte enumeration is not feasible.

Here, double sampling procedure is taken to estimate the catch. The estimation procedure is as follows :

If x_i is the no. of operating unit in the i-th selected fishing village, then total no. of operating units in the ecosystem,

$$\hat{X} = \frac{N}{n'} X' \quad \text{Where } X' = \sum_{i=1}^{n'} x_i$$

and the estimate of the variance of $\hat{X}$ is given by

$$\hat{V}(\hat{X}) = N^2 \left(\frac{1}{n'} - \frac{1}{N}\right) s^2_x$$

and estimated total catch

$$\hat{Y} = \frac{N}{n'} \quad \frac{X'}{n} \quad \sum_{i=1}^{n} \frac{y_i}{x_i}$$

and the estimate of the variance of $\hat{Y}$ is given by

$$\hat{V}(\hat{Y}) = \frac{N^2}{n'^2} \quad \frac{X'^2}{n(n-1)} \left[\Sigma(y_i^2/x_i^2) - \frac{1}{n}\left(\Sigma \frac{y_i}{x_i}\right)^2 \right]$$

$$+ \frac{N(N-n')}{nn'(n'-1)} \left[X' \Sigma \frac{y_i^2}{x_i} - \left(\frac{X'^2}{n'}\right) \left(\frac{1}{n-1}\right) \left\{ \left(\Sigma \frac{y_i}{x_i}\right)^2 - \Sigma\left(\frac{y_i^2}{x_i^2}\right) \right\} \right]$$

(B) Landing Centre Approach

(i) When zone demarcation is feasible.

From the data on the selected fishing units, estimate for two six-hour periods are obtained and added to the night landings, if any, for the observed landing centre. On the basis of such landing centre-day estimates, zonal estimate is arrived at.

Sum of such zonal monthly estimates for required region gives rise to regional estimates. From monthly estimates seasonal and annual estimates are also obtained.

Zonal Estimates :

$$\hat{Y}_{ij} = \frac{N}{n} \sum_{k=1}^{n} Y_{ijk}$$

where Y_{ijk} is the total for the k^{th} landing centre-day in the j^{th} zone for i^{th} month and $\hat{Y}_{ij}$ is the estimate of total, for the j^{th} zone.

$$\hat{V}(\hat{Y}_{ij}) = \frac{N^2 s^2}{n}$$

where s^2 = sample mean square between landing centre days of j^{th} zone for i^{th} month, n and N are the sample and total number of landing centre days in the j^{th} zone and i^{th} month.

$$s^2 = \frac{1}{n-1} \left[\sum_{k=1}^{n} Y^2_{ijk} - \frac{(\Sigma Y_{ijk})^2}{n} \right]$$

when the first stage units are selected by S.R.S. with replacement.

This holds good also when the error involved in the other stage is negligible.

(ii) When zone demarcation is not feasible.

Let n sample centres are selected from a population of N and let d sample days are selected at the second stage in the following manner. A month is divided into three groups of ten days each. Select a sample of two consecutive days from first group and the corresponding systematic sample at an interval of 10 days (d = 6, K = 10) : Then

$$\hat{Y} = \frac{N}{n} \sum^{n} D_i \, \bar{y}_i$$

Where D_i = no. of fishing days at i-th centre in a month and the estimate of variance of $\hat{Y}$ is given by

$$\hat{V}(\hat{Y}) = N^2 \left(\frac{1}{n} - \frac{1}{N} \right) s_b{}^2 + \frac{N}{n} (k-1) \, \Sigma D_i \, s_{wi}{}^2$$

Where $s_b{}^2 = \frac{1}{n-1} \sum^{n} \left(D_i \, \bar{y}_i - \frac{1}{n} \Sigma D_i \, \bar{y}_i \right)^2,$

$$s_{wi}^2 = \frac{1}{2 \times (d-1)} \sum_{j=1}^{d-1} (y_{j+1} - y_j)^2$$

$\bar{y}_i = \frac{1}{d} \sum^{d} y_{ij}$, d = no. of sampling days.

CHAPTER—6

COLLECTION AND ESTIMATION METHODOLOGY FOR RESERVOIRS, LAKES AND BEELS

Most of the waterbodies in this class are controlled by the State Governments, fisheries development corporations and local bodies and their area statistics are accurately known and documented in the official records. They are being exploited mostly by private contractors by fixing catch quotas through gear regulation. Although a proper record of fish catch is also maintained by the concerned controlling agencies in order to adopt proper stocking and exploitation policies to obtain maximum sustainable yield on cotinual basis but it is felt that the above information may not be adequate in the present form and some sort of physical survey of these waterbodies on sampling basis at the time of harvesting becomes necessary with consolidation of information from different sources. Moreover, there are situations where some reservoirs are exploited round the year by various agencies such as fishermen cooperatives and private fishermen on the basis of fishing licenses. Records of catch by these agencies are not available precisely due to either non-maintenance of catch records and/or concealment of catch due to other reasons. Such type of situations require sample assessment of the catch by collecting information on the site from the fishing units at the time of fishing for reliable and precise estimate. In order to complete this task of data collection we need a standard procedure for assessing the fish production. The method narrated below can be followed for this purpose.

First of all divide all the waterbodies covered under this group into three categories on area basis.

Category I — 10 ha to 500 ha — Small reservoirs

Category II — 500 ha to 1000 ha — Medium reservoirs

Category III — More than 1000 ha — Large reservoirs.

Reservoirs belonging to category I are generally known in respect of their area and fish production as they are harvested once a year on the basis of catch quotas by auctioning them to private contractors/cooperative societies. So the area and fish production statistics may be computed from the agency records on total enumeration basis.

However, to cross check the above statistics, a sample of 5% to 10% of the waterbodies may also be selected at random for physical observation and enumerators may be sent for recording the data on the fishing day and the information may be furnished in proformae no. 1.3 and 2.2.

Reservoirs under category II and III are either harvested during a particular season by the above procedure or they are exloited round the year by cooperative societies/private fishermen on lease basis/license basis and/or royalty basis. The estimation of fish catch from this type of exploitation becomes rather difficult because of non-maintenane of catch records/sale deeds etc. by the exploiting agencies. Hence, there is an utmost need to have a data collection method based on scientific lines for assessment of catch from these reservoirs or lakes. The most feasible method of approach is detailed below for implementation in the field.

1. Prepare a complete census of the main units (boats, fishermen, markets etc.) and their components from the available official records or by frame surveys.

2. Select a sample of 10 to 20% units for collection of data on various aspects of fishery in proforma 2.2. This data may be collected from the fishing units at a particular location where they are usually landed.

3. In case of data collection at (2) sampling days in a month may also be fixed in advance. For this purpose it is advised to observe each centre for about 6 days in a month following the pattern of 2 selected consective days in 10 days.

4. Follow the estimation procedure discussed earlier under the head Landing Centre/Fishing Village approach (5·5).

CHAPTER—7

COLLECTION AND ESTIMATION METHODOLOGY FOR ESTUARIES AND LAGOONS

Estuaries and lagoons contribute substantially to fish production in the country. The assessment of fish yield from these ecosystems needs a methodology suitable to the prevailing practices with regard to fishing and marketing. Practical experience and the experience of various other workers reveal that these ecosystems are exploited by fishing effort employed in the form of mechanised small trawlers to non-mechanised country boats and the entire catch in most of cases is unloaded at a specified place called fish landing centres. Hooghly-Matlah and Chilka are such examples having established landing centres which remain in operation throughout the year. However, during winter fishing some new landing centres also come up.

Therefore, the landing centre approach is found to be most suited to these ecosystems for estimation of fish production. The following steps may be initiated in order to make assessment surveys of these water system a success.

7.1 The Sampling Frame

Collection of data on required items of information calls for construction of some frame which is utilised for selection of sample. In the present case a frame of population units should be prepared in the form of a map or chart showing the location of the principal points of landing/fishery economic units/ fishing villages as the case may be for each of the fishing grounds and the above frame may then be used for selection of sample.

7.2 Organization of Field Work

After selecting the sample of units, a comprehensive programme of field observation should be formulated and handed over to the trained enumerators and sampling in time and space may be finalised depending upon the local situation. This information including the sampling frame and other related components may be entered into proforma no. 1.3 and sent to the Project office before commencement of the actual survey.

7.3 Type of Data to be Collected

The type of information normally available at the landing centres and designed in the proforma schedule no. 2.3 should then be collected by sampling of the selected landing centres. This information may include species-wise landings (only commercially important ones), fishing effort etc.

7.4 Sampling Design

The ecosystem may first be divided into number of homogenous zones according to practical covenience and from each zone a few landing centres may be selected depending upon the availability of manpower and resources. But it is advisable to select all the potential landing centres and then follow sampling in time and space. For that a month is divided into three sets of ten days each. Select a sample cluster of two consecutive days for the first set and then systemetic sample with a sample interval of ten days. In this way 6 days sampling in a month would be done at each landing centre. For example, if the two consecutive days selected are, say, 3rd and 4th day then the remaining sample days for observation would be $(3+10) = 13$th day, $(4+10) = 14$th day and $(13+10) = 23$rd day, $(14+10) = 24$th day of a month.

7.5 Estimation Procedure

The method of estimation suggested under 5.5(B) may be followed.

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APPENDIX—1

List of Schedules

Sl. No.	Schedule No.	Subject
1.	1.1	Resources Survey of Ponds and Tanks.
2.	1.2	Resources Survey of Beels.
3.	1.3	Resources Survey of Reservoirs and Lakes.
4.	1.4(a)	Inventory of Fishing Village. Craft & Gear. (Survey under rivers/streams/lagoons/ estuaries).
5.	1.4(b)	Inventory of Landing Centres (Survey under rivers/streams/lagoons/estuaries).
6.	2.1	Fish catch statistics from selected tanks and ponds.
7.	2.2	Fish catch from reservoirs/lakes/beels.
8.	2.3	Fish catch from landing centres for estuaries and lagoons.
9.	2.4	Fish catch from rivers and streams.

Schedule1.1 : RESOURCES SURVEY OF PONDS AND TANKS

Sample Code: State/District/Stratum/Cluster

A. Identification

1. Village:
2. Panchayat/Anchal:
3. Police Station:
4. Tehsil/Taluk/Sub-division:

STATE:
DISTRICT:
YEAR:

B. Details of water units:

Sl. No.	Revenue Settlement Record Plot No. (S)	Ownership Private/Public/Government	Type of Unit	Water Area (ha)			Seasonality (Period of water retentions in months)	Source of water	Depth (m)		Soil Type	Extent of Silting
				Revenue Settlement record	Max.	Min.			Av. of max. water	Av. of min water		
B 1	B 2	B 3	B 4	B 5	B 6	B 7	B 8	B 9	B 10	B 11	B 12	B 13

Utilization for fish Culture	Reason for non utilization for fish production	Artificial feed used (Yes/No)	Manure/Fertilizer (Yes/No)	Normal duration of crops (months)	Aquatic weeds (%)	Stocking (Yes/No)	If leased		Months of fishing	Av. production per yr. (kg)	REMARKS
							Duration of lease	Lease rent per yr.			
B 14	B 15	B 16	B 17	B 18	B 19	B 20	B 21	B 22	B 23	B 24	B 25

FISH CULTURE EXPLOITATION AND PRODUCTION DETAILS

Sl. No.	Fish Culture system	Species cultured	Stocking ratio	Date of Stocking	Number stocked			Normal duration of crop (months)
					Spawn	Fry	Fingerlings	
C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9

Whether under any programme (name)	Bulk catches			Sporadic catches			Disposal of catch		Draw the location of the pond
	Months of fishing	No of days per month	Yearly production (Kg)	Months of fishing	No. of days per month	Yearly production	Distribution (%)	Sale (%)	
C 10	C 11	C 12	C 13	C 14	C 15	C 16	C 17	C 18	C 19

Schedule 1.2 : RESOURCES SURVEY OF 'BEELS'

State....................District......................Sub-division......................

A 1 Water body identity

Sl. No.	Name	P. S.	CD Block	VILLAGE (S)		Settlement Record Number
				Name	JL. No.	
A 11	A 12	A 13	A 14	A 15	A 16	A 17

A 2 Ownership and fishery management

Ownership	LEASED FISHERY TO		Fishery management system	Reasons for non-utilization
	Name	Lease duration (yr)		
A 21	A 22	A 23	A 24	A 25

A 3 Physical characteristics

	AREA (ha)		DEPTH (m)					Mar. land Utilization		SILTATION	
			MONSOON		SUMMER						
Settlement Records	Monsoon Max.	Summer Min.	Max.	Av.	Max.	Av.	SHAPE	Vegetation	Area (ha)	Silt depth	Rate cm/yr.
A 301	A 302	A 303	A 304	A 305	A 306	A 307	A 308	A 309	A 310	A 311	A 312

A 4 Water flows characteristics

FEEDING RIVER		OUTLET STREAMS		WATERGATES			
Name	Months of inflow	Name	Months of functioning	Inlet Stream Name	F/D	Outlet Stream Name	F/D
A 41	A 42	A 43	A 44	A 45	A 46	A 47	A 48

A 5 Aquatic weed infestation

FLOATING		SUBMERGED	
Month	Cover	Month	Cover
A 51	A 52	A 53	A 54

A 6 Seed stocking

NATURAL				DEVELOPMENTAL SEEDING							
				LAST STOCKING DETAILS							
						SEED		% COMPOSITION			
Stream	Months	Major species	Av. no/yr.	Date	No.	Size	Source	C	R	M	Others
A 601	A 602	A 603	A 604	A 605	A 606	A 607	A 608	A 609	A 610	A 611	A 612

B. Fishery Exploitation.

B 1. Inventory of fish production potential

Management system and controlling authority	No. of active fisherman	No. of Boats	NETS				
			Type	No.	Size	Main fishes caught	Months of operation
B 11	B 12	B 13	B 14	B 15	B 16	B 17	B 18

B 2 Catch and its disposal

	FISHING		LANDING CENTRES		CATCH (Kg)			DISPOSAL %		
Type of catch	Months	Days/Month	Village	No. of centres	Kg	%	Major Species	Local Sale	Distant Market	Domestic use
B 201	B 202	B 203	B 204	B 205	B 206	B 207	B 208	B 209	B 210	B 211
Bulk (B) Sporadic (S)										

C 1 Nearest available fisheries departmental staff at .... distance .... Km..............

C 2 Surveyed by (Name) .... Signature .... Date(s) ....

C 3 Supervised by (Name) .... Signature .... Date(s) ....

C 4 Data transferred on Register No .... Page ....

C 5 Checked by (Name) .... Signature ....

Schedule 1.3 : RESOURCES SURVEY OF RESERVOIRS & LAKES

A. 1 State .... A. 2 Irrigation Division .... A. 3 Circle ....

B. Details of water bodies

Sl. No. & Name (if any)	Location			Year of construction	River	Purpose	Seasonality	Capacity at FRL (ha m)	Area at FRL (ha)	Area at MRL (ha)
	District	Block	Village (if any)							
B 1	B 2	B 3	B 4	B 5	B 6	B 7	B 8	B 9	B 10	B 11

Depth (m)		Principal months of irrigation	Main Fishery	Managed by	Fishing by individual/ Cooperative/ Corporation/ Govt. agency	Mode of exploitation	License fee/ Royalty, if any (Rs.)	Estimated Annual Production (t)	Value of produce (gross)
Full level	Min. level								
B 12	B 13	B 14	B 15	B 16	B 17	B 18	B 19	B 20	B 21

Write NA if not applicable.

Name of the Supervisor

Name of the Enumerator

Schedule 1.4 (a) : SURVEY UNDER RIVERS/STREAMS/LAGOONS/ESTUARIES

Inventory of fishing villages & crafts and gear

Name of the river/stream :	Total no. of fishing villages :	State :
Name of the fishing zone :	Location of the fishing zone :	District :
Name of the selected village :	Block :	Year :
		Month :

Name of operating fisherman	Family members		Engaged in fishing		Principal occupation	Part time occupation	Season of operation
	Adult	Children	Adult	Children			
1	2	3	4	5	6	7	8

Mode of disposal of catch	Monthly income from fishing	No. of fishing boats				No. of fishing gear										
		a	b	c	d	BN	GN	DN	CN	T	P	S	HL	TN	SN	PBO
9	10	11				12										

Note : a— Non-mechanised boat<(10 ft)
b— Non-mechanised boat ≥(10 ft)
c— Mechanised boat
d— Small trawlers

BN— Bag net
GN— Gill net
DN— Drag net
CN— Cast net

T— Traps
TN— Trawl net
SN— Seine net
P— Purses

S— Scoop net
HL— Hook and line
PB— Plung Busket
O— Others (Specify)

Name of the Supervisor

Name of the Enumerator

Schedule 1.4 (b) : SURVEY UNDER RIVERS/STREAMS/ESTUARIES/LAGOONS

INVENTORY OF LANDING CENTRES

State :
Year :
Month :

Name of the river/stream:
Name of fishing zone:

Sl. No.	Name of landing centre	Location			Perennial/ seasonal (P/S)	No. of fishing boats landed per day	Fishing gear commonly used (give code No.)
		District	Block	Village			
1	2	3	4	5	6	7	8

Does it receive catch from other source if so, name it	Weighing facilities Yes/No	Total catch per month (by enquiry)	Remarks
9	10	11	12

Name of the Supervisor

Name of the Enumerator

Schedule 2.1. : FISH CATCH STATISTICS FROM SELECTED TANKS AND PONDS

Month :
State :
Year :

1. Identification Particulars :
   - (a) Code No. of Sample water unit :
   - (b) Name of the fish farmer :
   - (c) Name of the village :
   - (d) Name of the Tehsil/Taluk Sub-division and District :
   - (e) Revenue/Settlement Record Plot No (s) :
   - (f) Water area (ha) :
   - (g) Fertilizer/Manure used : Yes/No
   - (h) Artificial feed given : Yes/No
   - (i) Date of sampling :
   - (j) Date of last sampling :
   - (k) No. of netting days in between :
     - (i) During the present month :
     - (ii) During the previous month :
   - (l) Seasonality of observation :

2. Stocking details :

Date	Species	Number stocked	Stocking size (mm)

3. Fish catch by enquiry

Date	Species (%)	Total catch (Kg)	Manpower engaged

4. Physical observation of fish catch:

Date	No. of hauls	Man power engaged	Type of gear used	Total catch	Species-wise catch (%)

5. Mode of disposal

At site	Given for wages	Self con-sumption	Whole sale/ Retail Market	Others if any

Name of the Supervisor

Name of the Enumerator

Schedule 2.2. : FISH CATCH FROM RESERVOIRS/LAKES/BEELS

1. Identification particulars
   (a) Sample Code : (b) Name of the selected water body :

State :
Year :
Month :

2. Stocking details :

Date	Species	No. stocked	Size

3. (a) Name of Landing Centre : (b) Block : (c) District :
4. Details of fish catch :—
   (a) Date of last sampling : (b) Date of sampling : (c) Seasonality of observation :
   (d) Record of fish catch during the period :

Date	Gear used		Type of craft	Manpower used	Time of operation	Total catch	Specieswise catch (%)		Mode of disposal				
	Type	Nos.							At site	Given for wages	Seif consumption	Whole sale/ Retail Market	Others (if any)

Name of the Supervisor

Name of the Enumerator

Schedule 2.3. : FISH CATCH FROM SELECTED LANDING CENTRES FOR ESTUARIES AND LAGOONS

Identification :

State :
Year :
Month :

1. (a) District :
   (b) Block :
   (c) Village :
2. Name of the water system :
3. Name of the fishing zone :
4. Name of the landing centre :
5. (a) Date of sampling :
   (b) Date of last sampling :
   (c) No. of fishing days between the two sampling days
      (i) During the previous month :
      (ii) During the current month :

6. Fishing units operated :

	1	2	3	4	5
Type					
Number					

8. Gearwise observation

Fishing unit	2	3	4	5
(i) Name of observed gear (local name)				
(ii) Type of gear				
(iii) Tides of operation (LT/HT/LT/HT)				
(iv) Catch of tide no.*				
(v) Species catch				
1				
2				
3				
4				
5				
6 Others				
Total catch				

*First low tide (LT) - 1
First high tide (HT) - 2
2nd low tide (LT) - 3
2nd high tide (HT) - 4

Within 24 hours from 1800 hrs of previous day to 1800 hrs on the date of observation

Name of the Supervisor

Name of the Investigator

Schedule 2.4. : ESTIMATION OF FISH CATCH FROM RIVERS AND STREAMS

Identification particulars

State :
Year :
Month :

1. Name of the water system :
2. Name of the fishing zone :
3. Name of the landing centre/fishing village
   Village :
   Block :
   District :
4. Date of last sampling :
5. Date of sampling :
6. Time of sampling :
7. No. of fishing days between two sampling days :
   (i) During the last month :
   (ii) During the current month :
8. Fishing Units Operated

	1	2	3	4	5
Type					
Number					

9. Observation of catch and effort

Sl. No.	1	2	3	4	5	6
Type of gear						
Period of operation						
Manpower used Adult :						
Children :						
Species-wise catch						
1						
2						
3						
4						
5						
6						
Total catch						

Mode of disposal :

1. At site
2. Self consumption
3. Whole sale/retail market
4. Any other (specify)

Name of the Supervisor

Name of the Investigator

APPENDIX—2

Code List for Schedules

LIST OF CODES FOR SCHEDULE 1.1

State — 2 digit code

State	Code	State	Code
Andhra Pradesh	01	Manipur	12
Assam	02	Meghalaya	13
Bihar	03	Nagaland	14
Gujarat	04	Orissa	15
Haryana	05	Punjab	16
H . P	06	Rajasthan	17
Jammu & Kashmir	07	Sikkim	18
Karnataka	08	Tamil Nadu	19
Kerala	09	Tripura	20
Madhya Pradesh	10	Uttar Pradesh	21
Maharastra	11	West Bengal	22

	Stratum —	1 digit code
	Cluster —	1 digit code
A.1	Village —	2 digit code
A.2	Panchayat/ Anchal —	2 digit code
A.3	Police Station —	2 digit code
A.4	Tehsil/ Taluk/Sub-division —	2 digit code

(Above codes to be allotted at Project Head Quarters.)

B.1	Serial No.	
B.2	Plot No. —	Actual Figures

B.3	Ownership	1 digit code Private — 1 Public — 2 Government — 3

B.4 Type of Unit — 1 digit code

Freshwater Nursery	— 1	Freshwater Bheri	— 4
Stock Pond	— 2	Brackishwater Pond	— 5
Freshwater nursery		Brackshwater Bheri	— 6
cum stock pond	— 3	Any other	— 7

B.5 to B.7 Water area (ha) — 6 digit : 4 digits for whole number and 2 digits for decimal.

Say : Water area 2.5 ha : Code — 000250

.05 ha : Code — 000005

B.8 Seasonality — 1 digit code

12 months or perennial	— 1
9-12 months or long seasonal	— 2
6-09 months / seasonal	— 3
3-06 months / short seasonal	— 4
Less than 3 months	— 5

B.9 Source of water — 1 digit

Rain fed	— 1	Sewage	— 5
River channel	— 2	Estuaries / Coastal	— 6
Irrigation canal	— 3	Others	— 7
Ground water	— 4		

B.10 to B.11 Depth (in Mtrs.) — 4 digit code (3 digits for whole number & 1 digit for decimal figures)

(for 2.5 m depth the code will be 0025)

B.12 Soil type — 1 digit code

Sandy	— 1	Sandy clayey	— 5
Clayey	— 2	Sandy loam	— 6
Loamy	— 3	Clay loam	— 7
Rocky	— 4	Others	— 8

B.13 Extent of silting — 2 digit code

First digit for characters and 2nd digit for pattern of silting.

Characters		**Pattern**	
Not silted	— 1	Natural process	— 1
Partially silted	— 2	Man made	— 2
Heavily silted	— 3		

B.14 Utilization for fish culture — 2 digit code : One digit for utilization and other for culture system.

Utilization		**Culture Systems**	
Not used	— 0	Absence of any culture system	— 0
Fish culture	— 1	Carp culture with irregular stocking only	— 1
Irrigation cum fish culture	— 2	Carp culture with regular annual stocking	— 2
Bathing and washing & fish culture	— 3	Scientific culture	— 3
Drinking water / temple etc. (not used for fish culture)	— 4	Brackishwater prawn / fish without stocking	—4
Irrigation only	— 5	Brackishwater prawn with stocking	— 5
		Brackishwater fish with stocking	— 6

B.15 Reasons for non-utilization — 1 digit code

Not applicable	— 0	Weed problem	— 4
Multiple ownership	— 1	Poaching	— 5
Disintersted ownership	— 2	Any others	— 6
Disputed	— 3		

B.16	Artificial Feed	—	1 digit code	
			Yes	— 1
			No	— 0
B.17	Mannure / Fertilizer	—	1 digit code	
			Yes	— 1
			No	— 0
B.18	Normal duration of carp (months)	—	2 digit code	
B.19	Aquatic weed (%)	—	2 digit code	
B.20	Stocking	—	1 digit code	
			Yes	— 1
			No	— 0
B.21	Duration of lease (Years)	—	2 digit code	
			Not leased	— 00
B.22	Lease rent per year (Rs.)	—	4 digit code	
B.23	Months of fishing	—	1 digit code	
			January — April	— 1
			May — August	— 2
			Sept. — Dec.	— 3
			January — Dec.	— 4

B.24 Average production per year (in Kg) — 5 digit code

e.g. production	—	150 Kg code — 00150
,,	—	50 Kg code — 00050
,,	—	1125 Kg code — ·01125

C.2 Fish culture system — 1 digit code

Culture system		**code**
Freshwater fish without stock	—	0
Carp culture with irregular stocking only	—	1
Carp culture with regular stocking only	—	2
Scientific culture	—	3
Brackishwater prawn / fish culture without stocking	—	4
Brackishwater prawn culture with stocking	—	5
Brackishwater fish with stocking	—	6
Any other	—	7

Instructions for entry of data and information on Schedule 1.2

Note : For each 'beel' one schedule is to be filled

Column No.	Explanation of data entry method
A 11	Serial number shall be allotted for each subdivision.
A 12 — A 17, A 23	Self-explanatory
A 21	The department owning the waterbody is to be entered e.g. Revenue Dept., Forest Dept. followed by a second entry controlling the fishery rights e.g. Fisheries Dept., Fisheries Corporation.
A 22	Lessee may be identified as contractor, fishery co-operatives (if more than one, put the number within brackets), Corporation.
A 24	Indicate management system by the following codes :

	Code
Outright auction	OA
Licensing of fisherman	LF
,, ,, boats	LB
,, ,, nets	LN
Royalty system departmental fishing	R
Government Departmental fishing	G

A 25 — Indicate principal reason for non-utilisation for fishery production in one digit code

Reason	**Code**
Weed choked	1
Poor fish population / not stocked	2
Litigation	3
Departmental decision	4
Any other	Specify the reason in brief

Entries under block A-3 will be by enquiry / observation :

A 301 to 307	Self explanatory
A 308	Put coded information in one digit

Shape	**Code**
Rectangular	1
Long Strip	2
U or J shape	3
Circular	4
Irregular	5

A 309	Indicate marginal vegetation as — Paddy, Jute, etc. followed by area occupied by crop in hectares.
A 311, A 312	The level of siltation may be ascertained and entered, if available. The rate of annual deposit to be indicated in cm./yr.
A 41 to A 44	The inlet feeding rivers (A 41) and outlet stream (A 43) to be named here with months of feeding or outflow in two digit codes (January as 01 to December as 12) for writing months.
A 45 to A 48	The streams on which watergates (sluices) are provided may be written, indicating in A 46 and A 48 if they are dead (Silted for filled up) as "D" and if functional as 'F'.
A 51 to A 54	The incidence of weed infestation may be given season-wise over which there is marked change in density. The cover may be indicated as percentage of total area, while season in month codes e.g. summer from February to May as 02 — 05.
A 601 to A 612	Mostly self-explanatory. If no seeding is done leave A 605 — A 612 blank. C, R, M, refer to catla, rohu and mrigal. The source of seed in A 608 may be indicated as 'River Seed (R)' or 'Induced bred (IB)' or 'Bundh bred (BB) if known.
B 11	Repeat information from A 22 and A 24.
B 12	Enlist the total active fishermen operating in beel.
B 13	Enlist the total number of boats operating in beel for fisheries.
B 14 to B 18	Enlist the total nets of each type individually with their details e.g. for Drag nets, Gill nets etc. Block B 2 refers to catch and its disposal. Two types of catches are primarily envisaged. Commercial 'Bulk' (B) and commercial cum subsistence sporadic (S). Give details of such catches separately in two lines in cols B 202 — B 211. This data has to be collected by careful enquiry. In the case of distant market sale, under B 210, indicate the name of market also, while in B 209 indicate the names of villages also where disposed.

Instructions for entries of data on Schedule 1.3

B 1 to B 6	Actual information
B 8	Seasonality — Same as in B 8, Schedule 1.1

B 9 to B 12, B 7	Self explanatory
B 14	Two digit Code stating the Sl. No. of the month.
B 15	Main fishery — Name of the speices
B 16	Managed by — One digit code

Fisheries Department — 1
Corporation — 2
Cooperative Society — 3
Gram Panchayat — 4
Others — 5

B 17 Fishing by — One digit code

Individual — 1
Cooperative Society — 2
Corporation — 3
State Govt. — 4

B 18 Mode of exploitation — One digit Code

Free fishing	— 1	Royalty	— 4
Licensing	— 2	Any other mode	— 0
Lease	— 3		

Instructions for entry of data on Schedule 1.4(a) & (b).

1 to 8 Self explanatory

9 Mode of disposal — One digit code

At site — 1
Whole sale market — 2
Retail market — 3
Middle man — 4
Any other — 5

11 Fishing boats

Non-mechanised boat $<$ 10 ft — 1
Non-mechanised boat $\geqslant$ 10 ft — 2
Mechanised boat — 3
Small trawlers — 4

12 Fishing gears :—

Fishing gear	Code
Bag net	BN
Gill net	GN

Drag net	DN
Cast net	CN
Traps	T
Trawl net	TN
Seine net	SN
Purses	P
Scoop net	SN
Hook and line	HL
Plung busket	PB
Others	O

APPENDIX—3

BASIC SAMPLING METHODS

Simple Random Sampling

Notations

N=Total number of units in the population.

n=Size of the sample

y_i=i-th observation for the character under study.

$\overline{Y}=\frac{1}{N}\sum_{i=1}^{N} y_i$, mean of the population.

Estimated mean and variance

$$\text{Estimated mean}=\hat{\overline{Y}}=\overline{y}=\frac{1}{n}\sum_{i=1}^{n} y_i$$

$$\text{Estimate of variance of } \hat{\overline{Y}}=\hat{V}(\overline{y})=\frac{N-n}{n\ N}\ \frac{1}{n-1}\sum_{i=1}^{n}(y_i-\overline{y})^2$$

Stratified Sampling

Notations

N=Total number of units in the population.

N_i=Total number of units in the i-th stratum of the population.

$W_i=N_i/N$

n=Total sample size.

n_i=Sample size of the i-th stratum.

L=Number of strata.

y_{ij}=The j-th sample observation of the character under study in the i-th stratum.

Estimated mean and variance

Estimate of mean in i-th stratum $= \bar{y}_i = \frac{1}{n_i} \sum_{j=1}^{n_i} y_{ij}$

Estimate of variance of $\bar{y}_i = \hat{V}(\bar{y}_i)$

$$= \frac{N_i - n_i}{n_i \; N_i} \frac{1}{n_i - 1} \sum_{j=1}^{n_i} (y_{ij} - \bar{y}_i)^2$$

Overall estimate of mean $= y_{st} = \sum_{i=1}^{L} W_i \bar{y}_i$

Estimated variance of $\bar{y}_{st} = \hat{V}(\bar{y}_{st}) = \Sigma W_i^2 \frac{N_i - n_i}{N_j} \quad \frac{s_i^2}{n_i}$

where $s_i^2 = \frac{1}{n_i - 1} \sum_{j=1}^{n_i} (y_{ij} - \bar{y}_i)^2$

Cluster Sampling

Notations

N = Number of clusters in the population.

n = Number of clusters in the sample.

M = Number of elements in the i-th cluster,

(i = 1, 2,...... , N. For simplicity, the case of equal cluster size has been considered.)

y_{ij} = Value of the character under study for the j-th element in the i-th cluster.

(j = 1, 2,......M ; i = 1, 2,......N)

$\bar{Y}_i = \frac{1}{M} \sum_{j=1}^{M} y_{ij}$, mean per unit for the i-th cluster

$\bar{Y} = \frac{\sum_{i=1}^{N} \sum_{j=1}^{M} y_{ij}}{N \; M}$, mean per unit of the population.

Estimate of mean and variance

Estimate of population mean $(Y) = \hat{Y}_{cl} = \frac{1}{n} \sum_{i=1}^{n} \bar{Y}_i$

Estimate of variance $= \hat{V}(\hat{Y}_{cl}) = \left(\frac{1}{n} - \frac{1}{N}\right) s_b^2$

where $s_b^2 = \frac{1}{n-1} \Sigma (\overline{Y}_i - \hat{\overline{Y}}_{cl})^2$

Two—stage Sampling

Notations

N = Number of primary sampling units (p. s. u.) in the population.

n = Number of primary sampling units in the sample.

M_i = Number of secondary sampling units (s. s. u.) in the i-th p. s. u.

m_i = Number of secondary sampling units selected from i-th p. s. u.

Y_{ij} = Value of the character under study for j-th s. s. u. of i-th p. s. u. of the population.

($j=1, 2, \ldots\ldots M_i$, $i=1, 2, \ldots\ldots N$)

y_{ij} = Value of the character under study for j-th selected s. s. u of i-th selected p. s. u.,

($j=1, 2, \ldots\ldots m_i$, $i=1, 2, \ldots\ldots n$)

$\overline{Y}_i = \frac{1}{M_i} \Sigma Y_{ij}$, population mean for i-th p. s. u.

$$\overline{Y} = \frac{\sum_{i=1}^{N} M_i \hat{\overline{Y}}_i}{\sum_{i=1}^{N} M_i}$$, population mean for the character under study.

$$\overline{M} = \frac{1}{N} \sum_{i=1}^{N} M_i$$, average number of s. s. us per p. s. u.

$$\hat{\overline{Y}}_i = \frac{1}{m_i} \sum_{j=1}^{m_i} y_{ij}$$, sample mean for i-th p. s. u.

Estimated mean and variance

An unbiased estimator of the population mean Y, is

$$\hat{\overline{Y}} = \frac{1}{n\overline{M}} \sum_{i=1}^{u} \frac{M_i}{m_i} \sum_{j=1}^{m_i} y_{ij} = \frac{1}{n\overline{M}} \sum_{i=1}^{n} M_i \hat{Y}_i$$

The estimated variance of $\hat{\overline{Y}}$ is given by

$$\hat{V}(\hat{\overline{Y}}) = \left(\frac{1}{n} - \frac{1}{N}\right) s'^2_b + \frac{1}{nN} \sum_{=1}^{n} \frac{M_i^2}{\overline{M}^2} \left(\frac{1}{m_i} - \frac{1}{M_i}\right) s_i^2$$

where $s'^2_b = \frac{1}{n-1} \sum_{i=1}^{n} \left(\frac{M_i \hat{\overline{Y}}_i}{M} - \hat{\overline{Y}}\right)^2$

and $s_i^2 = \frac{1}{m_i - 1} \sum_{j=1}^{m_i} \left(y_{ij} - \hat{\bar{Y}}_i \right)^2$

Systematic Sampling

Notations

N = Number of units in the population.

n = Number of units in the sample.

k = Number of systematic samples.

y_{ij} = Value of the character under study in the j-th unit of the i-th systematic sample.

$(j=1, 2, \ldots\ldots n, \quad i=1, 2, \ldots\ldots k)$

$\bar{Y}_i = \frac{1}{n} \sum_{j=1}^{n} y_{ij}$, mean of the i-th sample.

y'_j = Value of the character for j-th unit in the selected sample.

$(j=1, 2, \ldots\ldots, n)$

Estimate of mean and variance

When $N=nk$

Estimate of mean $= \hat{\bar{Y}}_{sy} = \bar{y}_i$

(1) An approximate and biased estimate of variance is given by

$$\hat{V}(\hat{\bar{Y}}_{sy}) = \frac{N-n}{2Nn(n-1)} \sum_{j=1}^{n} (y'_{j+1} - y'_j)^2$$

(2) If the systematic sample is treated as a simple random sample, then an approximate variance is given by,

$$\hat{V}(\hat{\bar{Y}}_{sy}) = \left(\frac{1}{n} - \frac{1}{nk} \right) s_w^2$$

where $s_w^2 = \frac{1}{n-1} \sum_{j=1}^{n} (y_{ij} - \bar{y}_i)^2$

(3) If estimates of mean of two or more systematic sample means are available then variance can be estimated unbiasedly. The estimators based on m sub-samples of size n/m are used.

Estimator of mean $= \bar{y}_{sy \cdot m} = \frac{1}{m} \sum_{i=1}^{m} \bar{y}_i$,

$\bar{y}_i$ are the subsample means.

and $\hat{\bar{V}}(\bar{y}_{sy \cdot m}) = \frac{1}{m(m-1)} \sum_{i=1}^{m} (\bar{y}_i - y)^2$