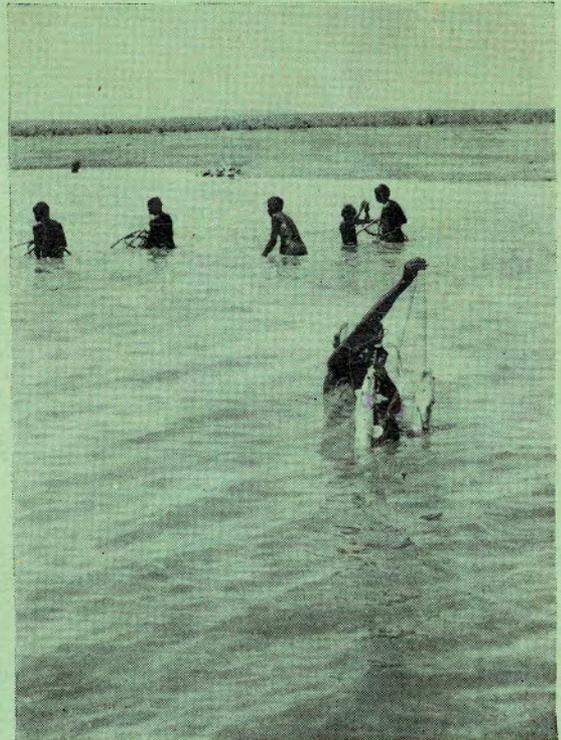




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METHODOLOGY ON RESERVOIR FISHERIES INVESTIGATIONS IN INDIA



Bulletin No. 12

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by

V.G. Jhingran
A. V. Natarajan
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There are a number of reservoirs in India which can readily be utilized for fish production on a large scale. The fact that so far the fishery potential of the existing reservoirs of India has not been developed is rather disappointing. There is appalling paucity of authentic data and knowledge of the resource itself and any statement on the present level of fish production in Indian reservoirs would be a mere guess. Stanly reservoir (Mattur Dam) is regarded to be the best managed and most productive of the Indian reservoirs with a fish production of about 40 kg per hectare (area about 155 sq.km and reported annual fish yield about 600 tonnes). This is a lone example of a productive reservoir in India comparing favourably with the Russian reservoirs. Average fish production from the Indian reservoirs hardly exceeds 6 or 7 kg per hectare. There is, thus, a great scope for fishery developmental activity in this sphere, which can result in impressive practical results.

The Indian Council of Agricultural Research has proposed a co-ordinated research project on Indian Reservoirs aimed at quick development of the fishery potential of selected reservoirs and compilation of biological, physico-chemical and other data in related disciplines on the basis of which such a development can be executed along scientific lines. In this production oriented research involving simultaneous exploitation of the resource and effecting appropriate management practices aimed at obtaining maximum sustained yield, adoption of standardized approach has been felt essential. It is the purpose of this bulletin to lay down such a standardized approach for the collection of various essentially required information and data on Indian reservoirs. This manual is not a text-book on methodology of Reservoir fisheries investigations and its scope is by no means comprehensive. It is an attempt at evolving practical methods using equipments available in India. Lack of mention of sophisticated foreign equipments may, therefore, be not interpreted as lack of knowledge of their use in advanced countries.

It is felt necessary to have two types of programmes: one, the short-range investigations capable of yielding enhanced fish production within two years of the commencement of investigations, and the other rather detailed long-range investigations involving a more thorough and detailed probe into the realm of reservoir ecology. The short and long range investigations may be conducted either singly or simultaneou

ously in any body of water. Methodology to be adopted for sampling for various limnological and fishery biological characters is described in the following pages. Proformas are provided as appendices for each item of investigation.

1.1 Short-range investigations

The purpose of short-range investigation is to collect data on those features of limnology, quantitative biology and exploitation techniques which will provide sufficient information to indicate measures to be adopted for increased production in reservoirs. They are not substitutes for detailed investigations. Neither is much precision expected in the short-range investigations. Their sole object is to serve the immediate purpose of enhanced fish production. For limited items of study taken up under short range investigations, the user of this manual may consult its appropriate sections for methods for which references are indicated here.

(a) Morphometry of the reservoir

The following information may be collected :

1. Area of the reservoir
2. Gross volume of the reservoir
3. Area-capacity curve
4. Shore development
5. Volume development

(Consult Chapter 2 of the manual for details)

(b) Fish fauna

A complete list of the species of fish, commercial and non-commercial, occurring in reservoir may be prepared.

(c) Water analysis

1. Temperature
2. Turbidity
3. pH
4. Dissolved Oxygen
5. Alkalinity
6. Nitrate
7. Phosphate

(d) Fish food resources

1. Estimate plankton biomass by volume displacement method. Identify under broad heads like cladocera, copepods, rotifers, bacillariophyceae, myxophyceae, chlorophyceae, xanthophyceae, euglenales etc. Take only vertical hauls for study and express plankton volume per cubic metre. For methods see section 9.

2. Estimate bottom biota biomass per sq metre using displacement method. Identify items under broad group heads. To convert volume in ml of preserved material to 'live weight' in gms multiply by 0.98. Limit your studies to macro-organisms only. Use No. 40 sieve. For details see section 11.

3. Estimate the biomass of larger aquatic plants and express in kg/sq m. For methods see section 10.

(e) Utilisation of fish food resources

Study the food and feeding habits of all fishes, commercial and non-commercial. Divide the fish samples into assorted size groups and analyse gut contents on group basis and not on individual fishes. Express the average feed in volume and constituents in %. At least one analysis should be conducted each month for each species. For methods see sub-section 14.6.

(f) Breeding and recruitment

1. Study gonads of all fishes all the year round and assign appropriate stages as per scale of maturity. For methods see sub-section 14.4.

2. Locate the spawning grounds of fishes in the main reservoir as well as in the upper part of reservoir in riverine zone. List out the fishes for which no spawning ground could be located. Shooting or spawn collection nets may be used for river stretches joining the reservoir. See sub-section 15.4.

3. Note down the species, time of occurrence, area of occurrence of fingerlings. Record abundance of the fingerlings of fishes as reflected in the catch per unit of effort. For details see sub-section 15.4.

(g) Yield, species and size composition

For details see section 12.

(h) Experimental fishing

For details see section 13.

(i) Stocking policy

For details see section 16.

1.2 Long-range investigations

The long-range investigations being taken up for studies in reservoirs are not tied down to immediate results. They cover more items of investigations and each requiring thorough analysis. The data collected under this head are, therefore, to be both elaborate and precise and their analyses thorough. The items of investigations requiring emphasis are as mentioned below: the details of the methodology are presented in the following chapters.

(a) Morphometry of the reservoir

(b) Water analysis

(c) Soil analysis

(d) Meteorological observations

(e) Primary productivity

(f) Plankton

(g) Larger aquatic plants

(h) Bottom biota

(i) Observations on existing fishing operations

(j) Experimental fishing

(k) Fishery biology

(l) Fish population dynamics

(m) Management policy

2 PHYSICAL AND MORPHOMETRIC FEATURES OF THE RESERVOIR

A correct knowledge of fish production per unit area or volume is very important both for assessing the productivity of a reservoir and for comparing it with those of other reservoirs. For this purpose certain morphometric data of the

2.4 Submerged contours of reservoir

Details of submerged contours such as are generally incorporated in the Project reports pertaining to the reservoir would suffice for limnological/fishery purposes. Prepare an area - capacity curve which gives in a nutshell the areas and corresponding capacities of contours.

2.5 Derived measures on morphometry

Compute the following derived measures :

2.5.1 Length of the shore line

This measure may be derived from reservoir maps, if suitable data are otherwise not available.

(a) Method I

Pin an inelastic thread along the reservoir boundary line on a large map and from the length of the thread, derive the length of the shore line making use of the scale of the map.

(b) Method II

The length of the shore line can be determined with the help of a divider.

2.5.2 Shore development

This parameter is frequently required to know how regular or irregular a shore line is.

(a) Method I

1. Represent shore line of reservoir in terms of map scale.
2. Represent area also in terms of same map scale.
3. Describe a circle (in terms of map scale units) that has an equal area of reservoir.
4. Divide the shore line length by the circumference of the circle.

5. The quotient is 1 if a reservoir has shore line in the form of a circle which is a remote possibility. The extent to which the ratio is above 1 depends upon how irregular the shore line is.

(b) Method II

A simpler way of deriving shore development is as follows :

$$\text{Shore development} = \frac{S}{\sqrt{\frac{a}{\pi}}} \quad \text{Where,}$$

S = length of shore line

a = area of reservoir

$$\pi = 3.14159$$

2.5.3 Volume development

Volume development is an index expressing the form of the water mass or the basin. To derive this, the following data are required :

1. Volume of the reservoir
2. The volume of a cone whose area of base is equal to the surface area of the reservoir and whose height is equal to the maximum depth of reservoir
3. Divide the volume of reservoir by the derived volume of cone as indicated in 2
4. The quotient is less than unity if the reservoir basin walls are essentially convex towards the water. The quotient is more than unity if the reservoir basin walls are concave towards the water.

3 WATER LEVEL AND INFLOW-OUTFLOW DATA

1. Mean monthly reservoir level with maximum and minimum (in metres)
2. Annual fluctuations of water level (in metres)
3. Monthly inflow into reservoir (t.cu.m)
4. Monthly outflow from reservoir (t.cu.m)

4 SAMPLING, METHODS OF COLLECTION AND ANALYSIS OF SAMPLES

4.1 General sampling procedure for different collections

(a) Zonal demarcations for sampling

It is desirable that reservoirs are demarcated into suitable sampling zones and this will necessitate detailed studies on reservoir topography, physico-chemical features and fauna and flora at the commencement of the investigations. To arrive at suitable zonal demarcations, it is necessary that the reservoir is arbitrarily divided into a number of transvers zones, each approximately of 0.5 to 2 km width depending on the area of the reservoir and these studied contour-wise (say, in terms of 2 metre contours : these may be reduced or enlarged according to requirements). In sampling, due attention should be given to lotic (riverine) zone, intermediate zone and lentic zones of reservoir, bays, shallow areas, vicinities of protected and exposed shores, islands, swampy areas etc. Special attention should also be given to certain physico-chemical features like vertical series of temperatures, dissolved oxygen, pH, free CO₂ etc. Detailed studies of fauna and flora taking into consideration the above biotopic niches carried out seasonally (say, summer, monsoon and winter) for a year would provide the basic data on which sampling zones and sampling frequency can be formulated.

The following sampling outline is suggested for plankton, bottom biota, larger aquatic plants and catch estimates.

(b) Sampling procedure for net plankton

Vertical plankton hauls should be taken from lotic (riverine), intermediate and lentic zones of the reservoir, covering all contours from the bottom. Non-net plankton sample shall be collected from various depths (say 1 m to 2 m intervals of depth) covering all contours. The samples from contours under each zone should be strictly on random basis. In sampling for plankton due attention should be given to sheltered areas, exposed shore, etc. in addition to certain physico-chemical features mentioned under headline "Zonal demarcations for sampling". The samples may be taken once a fortnight.

(c) Sampling procedure for bottom biota

The bathymetric distribution of bottom biota is governed by both depth and nature of substrata. Here also sampling may be done depthwise from lotic, intermediate and lentic zones. Each depth stratum, under different zones should be sampled randomly. In this manner natural variability due to differences between stratum is automatically eliminated from sampling error. Samples may be taken once a month or seasonally or even annually (depending on the life history of the bottom animals).

(d) Sampling procedure for larger aquatic plants

The sampling procedure for larger aquatic plants is similar to the one given for bottom biota. The samples may be taken once a month or seasonally.

(e) Estimation of fish yield, species and size-composition

Find out the number of landing centres/godowns/marketing centres for the fishery of the reservoir. It may be noted by observation whether fish landed in the above centres represent distinct fishing zones corresponding to various sectors of reservoir. Two days sampling per week may be allotted to each of the sectors for estimation of yield (which should include all fishes, commercial and non-commercial) choosing the days purely on random basis. The days all allotted for estimation of catch may also be used for studies of species and size composition of fishes.

In reservoirs where actual date to date zone-wise total catches are available the same may be recorded without recourse to sampling.

(f) Size of the sampling unit

Be it sampling for plankton or bottom biota or spawn collection or even for experimental sampling for fish, it is necessary to know the role of size of sampling units in sampling. Leaving aside the economics and other considerations, it is a general principle that for a particular amount of material sampled, greater accuracy is achieved by making each sampling unit as small in size as possible and having a correspondingly large number of sampling units.

(g) Random sampling and sampling error

Since considerable importance is given to random sampling in fisheries investigations, it is desirable to have a general idea as to what is random sampling and what is sampling error. To outline them briefly :

1. Each unit of population (in the statistical sense) has an equal chance of being included in the sample and each sampling unit is selected independently of the other sampling units.
2. The sample is capable of providing unbiased estimates of the characteristics of the population.
3. Sampling error is inversely proportional to the square root of the number of units in the sample.

4.2 General instructions on the depth-oriented observations and collection of samples for water analysis

Depth sounding and observation post location

Though details of reservoir topography are normally available ready-made with reservoir authorities, there are many observations in reservoir fisheries research which are depth-oriented. For example, depth details and locations are required for sampling points. The following method may be adopted for depth sounding and location of observation centre :

1. Sounding for depths may be done by 'sounding leads'. A 3 kg lead may be used for depths less than 9 metres and a 10 kg lead for greater depths. Use rope wire in the latter case.
2. Express sounding in actual and in terms of m.s.l.
3. Location of sounding positions may be done by sextant with telescopic sight tube. If any of the other complicated methods of 'location findings' is followed, it is desirable that assistance be taken from personnel trained in survey methods.

4. In the event of any of the above facilities for locating observation posts not being available, the same may be located approximately with reference to land marks.

(Note : If sonic devices like echo sounder are available, the same may be used for depth soundings)

4.3 Precautions for collection of water samples for chemical analysis

1. The time lapse between collection of sample and analysis should not normally exceed 72 hours.
2. Keep the sample in the dark and at low temperature if possible.
3. If preservatives are added (say, acid or other germicide), such preservatives should be clearly mentioned, along with analysis data.
4. Determination of temperature, pH and dissolved gases should always be carried out in the field, as otherwise, changes are almost inevitable by the time the samples reach the laboratory.
5. Time lapse may cause changes in pH-alkalinity-carbon dioxide balance resulting in the precipitation of calcium carbonate and decrease in the values for calcium and for total alkalinity.
6. Microbiological activity, should there be delay in analysis, may cause changes in the nitrate - nitrite - ammonia balance in addition to decreases in phenols and BOD.
7. Suspended matter in the water should be separated by decantation, centrifuging or by filtration.
8. In reservoirs, in initial stages of investigations, it is desirable to have separate samples for various zones in relation to depths. But subsequently, if such a procedure is not warranted, a 'composite sample' representing

the above would do. Either Friedinger or Kemmerer water sampler may be used.

9. Fortnightly sampling is desirable.
10. As a general rule results of chemical analysis of water are expressed as milligrams per litre (mg/l) or milliequivalents per litre (me/l). The me/l is obtained by dividing the concentration expressed in mg/l by the equivalent weight of the ion or the compound.

5. PHYSICAL AND CHEMICAL ANALYSIS OF WATER

5.1 Collection of water samples

Water samples are collected in different ways for different items of analysis. For dissolved gases, undue agitation, bubbling or mixing with air and other gases or entrainment of gas or air bubbles are to be avoided. A Kemmerer, Friedinger or Foerst type sampler may be used for collection. After collection, the water is let out through a rubber tube fixed to the bottom of the sampler which again is connected to a glass tube. The glass tube is slowly let into the sample bottle and water is allowed to fill in the bottle. For D. O. sample the water should be allowed to overflow at least three times the volume of the bottle taking care to avoid all bubbles. When such a sampler is not available and surface samples only are taken water may be collected by a large beaker or a plastic bucket and transferred to sample bottles by a siphon tube. The sample for dissolved oxygen should be fixed immediately after collection and preferably analysed on the spot. Analysis for carbon dioxide should be done immediately after collection and sample for free ammonia should be analysed on the spot or fixed with a few drops of sulphuric acid and taken to laboratory. Total alkalinity also should be done soon after collection because the loss of carbon dioxide from water may give different results if analysed later on. For more stable constituents of water, samples may be collected in a clean glass bottle, fixed with a few drops of chloroform or toluene and taken to laboratory but in no case the analysis should be delayed for more than seventy two hours. A representative sampling is usually done by collecting samples from a number of places and mixing them together to get a composite sample. This, however, cannot be done for dissolved gases for which separate sampling has to be done in the different depths. Determination of temperature, turbidity and pH should also be done on the spot.

Analysis of condition and constituents of water which are of primary importance are described below :

5.2 Temperature

Temperature plays an important role in limnological studies. It is usually determined by a centigrade thermometer in 0.1°C or when more accuracy is desired a thermometer graduated in 0.01°C may be used.

1. Surface water temperatures may be determined by collecting the water in a large plastic container and dipping the thermometer directly into the water, keeping it steady for about a minute and then noting the temperature. Temperature for water samples may be determined immediately after collection. As the solubility of oxygen is dependent on temperature it should be noted for the dissolved oxygen samples before fixing.

2. Subsurface temperature may be determined accurately by a reversing thermometer. This thermometer can be placed in any desired depth from a boat and by means of a trigger arrangement the thermometer is reversed at that point when the mercury column becomes fixed. It can then be taken up, temperature noted and the thermometer is reset for another observation. Indicate the temperature after effecting necessary corrections to the reading.

The mean temperature of the reservoir is derived from the vertical temperature records (i) by adding the temperatures limiting the upper (t_1) and lower (t_2) limits of each submerged stratum and dividing by 2 as $\frac{t_1 + t_2}{2}$ (ii) multiplying the above (a) by the percent by volume of each substratum in the volume of reservoir, being designated here as P(b) summing all terms $\frac{t_1 + t_2}{2} P$ corresponding to each stratum which constitutes the mean temperature.

5.3 Turbidity

Of the several methods used for the determination of turbidity the most accurate one is the photo-electric method but for field tests both Secchi Disc and U.S. Geological Survey turbidimeter can be used with fair accuracy.

(i) A standard Secchi Disc consists of a circular metal plate 20 cm in diameter, the upper surface of which is divided into four equal quadrants, each of them being painted black and white alternately while the lower side of the plate is painted black to eliminate reflection of light from that side. The disc is lowered on the graduated line into the water and the depth (d_1) at which it disappears is noted. Now the disc is lifted slowly and the depth (d_2) at which the disc reappears is noted. The reading $d_1 + d_2$ in cm gives a measure of light penetration and is known as Secchi disc transparency.

(ii) In U.S. Geological Survey method, two thin platinum wires, one relatively thicker than the other, are fixed in a metal ring, perpendicular to which is attached a metal rod graduated in mm. The water for turbidity determination is collected in a tall glass cylinder and the turbidimeter is slowly dipped into it until, looking from above the relatively thinner wire just disappears while the other wire remains visible. The reading can be expressed as mm which denotes inverse of turbidity or transparency of water or it may be converted to turbidity expressed as parts per million of silica using the U.S. Geological Survey Turbidimeter conversion table.

A still simpler modification of this method can be used with sufficient accuracy in the field. A bright metal pin is fixed at the end of a half meter scale and at right angles to it and it is dipped slowly into the water directly or collected in a tall glass cylinder till, while looking from above the pin just disappears from sight. The reading of scale at water surface is noted in mm and converted to turbidity as ppm of silica with the help of the same table given below :

U.S. Geological Survey Turbidimeter Conversion Table

Turbidimeter reading (mm)	Turbidity ppm (SiO_2)	Turbidimeter reading (mm)	Turbidity ppm (SiO_2)
1	2	3	4
20	1000	64	170
22	900	67	160
24	800	69	150
26	700	73	140
28	600	78	130

contd...

1	2	3	4
30	550	83	120
32	500	88	110
34	450	96	105
37	400	100	100
39	380	105	95
40	360	108	90
41	350	113	85
42	340	118	80
43	320	125	75
44	310	135	70
45	300	146	65
46	290	156	60
47	280	166	55
48	260	181	50
49	250	198	45
50	240	218	40
52	230	245	35
54	220	281	30
56	210	326	25
58	200	390	20
60	190	490	10
62	180		

5.4 pH

There are various methods for determining water pH. These may be broadly divided as electrometric and colorimetric.

i) Portable electric pH meter with glass electrodes and operated by batteries can be used in the field with good amount of precision. The sample is taken in a clean beaker and the electrodes, which should be thoroughly cleaned and wiped dry with filter paper, are dipped into it. The instrument is now operated according to the instructions associated with it and the indicating pointer records the pH directly. A calibration of the scale may be necessary with a buffer solution supplied with the instrument.

ii) Colorimetric methods which are more widely used can be taken up for clear water with sufficient accuracy but difficult to use for highly turbid or coloured water, though such waters are often made sufficiently clear by stirring them with a little neutral barium sulphate, allowing to settle and then decanting the clear liquid. At times, however, they present considerable difficulties and the results suffer from inaccuracy.

The principle of colorimetric estimation of pH is to develop colour in the sample with an indicator dye and to compare this with colour of glass discs, colour charts or coloured buffer solutions.

The indicators used with range of pH are given below :

<u>Indicator</u>	<u>pH range</u>
Bromo phenol blue	3.0 - 4.6
Bromo cresol green	3.8 - 5.4
Bromo cresol purple	5.2 - 6.8
Bromo thymol blue	6.0 - 7.6
Phenol red	6.8 - 8.4
Cresol red	7.2 - 8.8
Thymol blue	8.0 - 9.6

Place 10 ml of the sample in a small clear glass tube and add 0.5 ml of indicator. To know which of the above indicators is to be used a preparatory test with a universal indicator may be done which gives a very approximate value of the pH; otherwise phenol red would be used first and then if necessary indicators for higher or lower ranges. As the pH of inland waters generally varies between 6.0 and 9.6 the use of three indicators viz., Bromo thymol blue, Phenol red and Thymol blue may be sufficient. After adding the indicator to the sample, it is stirred gently and the colour developed is matched against colour discs in a comparator or standard colour charts, in the absence of which buffer solutions of different pH values may be prepared, treated similarly with indicators and kept in sealed tubes for comparison.

5.5. Alkalinity

In water analysis generally three types of alkalinities are differentiated viz., hydroxide alkalinity, car-

bonate alkalinity and bicarbonate alkalinity. These are determined by using separately two indicators, phenolphthalein and methyl orange for estimation of alkalinity. The alkalinities so determined are called 'P' and 'M' and then with the help of formulae containing P and M, the three types of alkalinities are determined. For all practical purposes however methyl orange alkalinity known as M.O.A. gives a measure of the acid combining capacity of the water.

Reagents

(a) 0.02 N H₂SO₄ : Measure out 30.0 ml of conc. H₂SO₄ sp. gr. 1.84 to one litre of distilled water to get approximately 1 N stock solution. To make 0.2 N solution take 20 ml of this stock solution and dilute to one litre. Check this standard against 0.02 N Na₂CO₃.

(b) Phenolphthalein indicator: .5 percent solution in 50% alcohol

(c) Methyl orange indicator : .05 percent aqueous solution

(d) Standard .02 N Na₂CO₃ :

Dissolve 5.3 gm anhydrous and carefully desiccated Na₂CO₃ in one litre distilled water. This is .1 N Na₂CO₃ stock solution. Dilute 50 ml of this .1 N Na₂CO₃ to 250 ml to give .02 Na₂CO₃.

Procedure

(i) Phenolphthalein alkalinity (P)

Take 50 ml of the sample in a conical flask placed over a white porcelain tile or in a white porcelain basin. Add 2 drops of phenolphthalein indicator. If the sample remains colourless P = 0. If the sample turns pink titrate with .02 N H₂SO₄ from a burette to a colourless end point.

$$P \text{ (as ppm CaCO}_3\text{)} = \text{No. of ml of .02 N H}_2\text{SO}_4 \times 20$$

(ii) Methyl orange alkalinity (M)

Proceed in the same way as before using methyl orange as indicator, the end point being indicated by a colour change from yellow to faint orange.

5.6 Dissolved oxygen

After collection, the sample should be fixed immediately and taken to laboratory for analysis or may be analysed on the spot.

Reagents

- (a) Alkaline iodide : Dissolve 700 gms of pure potassium hydroxide and 150 gms of reagent quality potassium iodide in 750 ml of distilled water. Cool and make up to one litre.
- (b) Manganous sulphate : Place 480 gms of $MnSO_4 \cdot 4H_2O$ in a large beaker and add 250 ml of distilled water. Pour the solution into a one litre flask. Continue addition of water to the beaker until all the manganous sulphate is dissolved. Make up to one litre with distilled water.
- (c) Concentrated sulphuric acid (Sp. gr. 1.84) C.P.
- (d) .025 N sodium thiosulphate : Dissolve 24.82 gms of crystalline $Na_2S_2O_3 \cdot 5H_2O$ in 700 ml distilled water, add 4 gms of borax ($Na_2B_4O_7 \cdot 10H_2O$) as a stabiliser; when borax has dissolved make up to one litre with distilled water. This gives .1 N $Na_2S_2O_3$. Keep it in a brown-glass stoppered bottle. This stock solution has to be standardised against .1 N $K_2Cr_2O_7$ solution.
- Dry crystalline potassium dichromate in an oven at $125^\circ C$, cool and weigh accurately 4.904 gm and dissolve it in distilled water to make one litre. Place 25 ml of this solution in a 250 ml conical flask, add one ml of alkaline iodide reagent, acidify with 2 ml concentrated H_2SO_4 and titrate the iodine liberated with .1 N $Na_2S_2O_3$ adding starch as indicator near the end point, completing the titration when the blue coloured solution suddenly turns colourless. Adjust the strength of the thiosulphate to exactly .1 N. Take 125 ml of this .1 N stock solution and dilute it to 500 ml to get .025 N $Na_2S_2O_3$.
- (e) Starch solution : Add 30 ml of 20% NaOH solution to a suspension of 2 gm powdered starch in 350 ml of distilled water. Stir the suspension until a thick syrupy, almost clear solution is obtained. Neutralise the alkali with HCl using litmus as indicator. Acidify with one ml glacial acetic acid. This starch solution is very stable.

Procedure

Remove carefully the stopper of the 100 ml sample bottle, add one ml of manganous sulphate reagent and one ml of alkaline iodide reagent by means of one ml pipette dipped to the bottom of the bottle and slowly drawing out as the reagents are added. Replace the stopper and invert the bottle three or four times for a thorough mixing of the reagents. A flocculant precipitate will be formed which will settle at the bottom. If the precipitate is whitish in colour, oxygen is very poor; light brown colour indicates poor oxygen while brown to red brown colour means medium to high dissolved oxygen. For quantitative estimation add one ml of conc. H_2SO_4 to dissolve the precipitate. Transfer 50 ml of this solution to a conical flask placed on white background and add $.025 N Na_2S_2O_3$ drop by drop till the colour turns pale yellow when one ml of starch solution is added to give a blue colour and the titration is completed by turning it colourless.

No. of ml of $Na_2S_2O_3$ solution X 4 = ppm of dissolved oxygen

5.7 Dissolved free carbon dioxide

As this is liable to escape easily from the sample, analysis should be done immediately after collection on the site.

Reagent

(a) $\frac{N}{44} NaOH$: Prepare $.1 N NaOH$ by dissolving about 4 gms of A.R. quality sodium hydroxide pellets and standardise it against $.1 N H_2SO_4$ using phenolphthalein as indicator. Dilute 100 ml of this $.1 N$ solution to 440 ml with distilled water. This is $\frac{N}{44} NaOH$ solution.

Procedure

Take 50 ml of the sample in a Nessler's tube add two drops of phenolphthalein reagent. If the water turns pink, there is no free carbon dioxide. When the water remains colourless add $\frac{N}{44} NaOH$ drop by drop from a 10 ml graduated pipette with a very gentle stirring with a glass rod till the colour turns pink.

No. of ml of $\frac{N}{44} NaOH$ required X 20 = ppm of free CO_2

5.8 Nitrogen

5.8.1 Ammonia nitrogen

For accurate determination of ammonia nitrogen, sample should be fixed with a few drops of sulphuric acid and the estimation done at the laboratory by distillation method but direct nesslerisation on the spot may be done with sufficiently accurate results.

Reagents

(a) Nessler solution : Dissolve 100 gm anhydrous mercuric iodide and 70 gm potassium iodide in a small quantity of ammonia free distilled water and add this mixture slowly, with stirring to cold solution of 100 gm NaOH in 500 ml of ammonia-free water. Dilute to one litre and keep in a brown coloured bottle in a cool place.

(b) Standard NH_4Cl solution : Dissolve 3.819 gm anhydrous NH_4Cl in ammonia-free distilled water and dilute to one litre (1 ml = 1 mg N). This is a stock solution. Dilute 10 ml of this to one litre with ammonia-free distilled water (1 ml = .01 mg N).

(c) Ammonia-free distilled water : This can be prepared by redistilling distilled water which has been treated with a slight excess of bromine and allowed to stand overnight.

(d) Phosphate buffer (pH 7.4) : Dissolve in distilled water 14.3 gm anhydrous monobasic potassium phosphate KH_2PO_4 and 68.8 gm anhydrous dibasic potassium phosphate K_2HPO_4 and dilute to one litre with ammonia-free water.

Procedure

(i) Direct Nesslerisation : Place 50 ml of the sample in a Nessler tube and 50 ml of ammonia-free distilled water in another tube. Add 2 ml of Nessler reagent in each. Now add standard NH_4Cl solution in small instalments in the distilled water, each time comparing the colour developed with the colour of the sample tube till a final matching is obtained. Repeat the procedure second time adding NH_4Cl standard just a little less than required for matching, wait for five minutes and obtain final matching by adding the required quantity of NH_4Cl solution as before.

No. of ml of NH_4Cl solution $\times .01 \times 20 =$ ppm of ammonia nitrogen

(ii) Distillation method : Thoroughly clean one 500 ml distillation flask, by distilling ammonia-free distilled water in it till the distillate shows negative result with Nessler solution. Now distil 500 ml of water sample after adding 10 ml of phosphate buffer and collect 200 ml of distillate. Place 50 ml of distillate in a Nessler's tube and proceed in the same way as before.

No. of ml of NH_4Cl solution $\times .01 \times 4 \times 2 =$ ppm of ammonia nitrogen

5.8.2 Nitrate nitrogen

Nitrate nitrogen may be determined in the laboratory in the sample fixed with chloroform or toluene.

Reagents

(a) Phenol disulphonic acid : Dissolve 25 gm phenol in 150 ml A.R. grade sulphuric acid in a flask, add 7.5 ml fuming sulphuric acid and heat on water bath for 2 hours. Keep in a dark bottle.

(b) Aluminium sulphate : 10% solution

(c) 12 N NaOH : Dissolve 480 gm of A.R. grade sodium hydroxide pellets in distilled water and make up to one litre.

(d) Standard KNO_3 solution (1 ml = .001 mg N) :

Dissolve .722 gm of KNO_3 in distilled water and make up to one litre. This stock solution contains .1 mg N per ml. Dilute 10 ml of this solution to one litre containing .001 mg N per ml.

Procedure

Evaporate to dryness 50 ml of the sample in a white porcelain basin on water bath. Cool and add 2 ml of phenol disulphonic acid drop by drop and rub it thoroughly with a glass rod. Wait for about 5 minutes and add 2 ml of aluminium sulphate solution. Now add 12 N NaOH solution slowly with stirring until it is alkaline. If nitrate is present

a yellow colour will appear. Remove aluminium hydroxide by filtration. Proceed similarly with standard nitrate solution as for ammonia determination.

No. of ml of standard nitrate solution requires $X \cdot 001$
 $X \cdot 20 = \text{ppm Nitrate} - N.$

5.9 Dissolved inorganic phosphate

Phosphate also may be determined in the laboratory in the samples fixed with chloroform.

Reagents

(a) Sulphuric acid (50%)

(b) Ammonium molybdate (10%)

(c) Acid molybdate reagent : This must be prepared fresh at the time of analysis. Add 15 ml of 50% of H_2SO_4 to 5 ml of 10% ammonium molybdate solution.

(d) Stannous chloride solution : Dissolve 2.15 gm A.R. quality stannous chloride ($SnCl_2 \cdot 2H_2O$) in 20 ml of conc. c.p. hydrochloric acid. When the solution is complete add sufficient distilled water to make 100 ml and place a small piece of mossy metallic tin in the bottle.

(e) Standard phosphate solution (1 ml = .01 mg P): Dissolve 4.388 gm of monobasic potassium phosphate (KH_2PO_4) which has been dried over sulphuric acid, in phosphate-free distilled water and make upto one litre. Place in a stoppered brown bottle. This stock solution contains 1 mg P per ml. Dilute 10 ml of this solution to one litre containing .01 mg P per ml.

Procedure

Place 50 ml of the sample in a Nessler tube, add 2 ml of acid-ammonium molybdate reagent and mix by gentle stirring, add 2 drops of stannous chloride, mix gently, wait for five minutes and match the blue colour developed with standards prepared in phosphate free distilled water similarly as for nitrate.

No. of ml of standard phosphate $X \cdot 01 X \cdot 20 = \text{ppm of P.}$

5.10 Dissolved organic matter

As an index of soluble organic matter in the water, oxygen consumed from permanganate may be determined, in the filtered sample after removing the particulate organic matter.

Reagents

(a) Standard KMnO_4 solution (1 ml = .1 mg O_2) : Dissolved .4 gm KMnO_4 in distilled water and make up to one litre. One ml of this solution = .1 mg O_2 . This solution should be standardised against ammonium oxalate solution in acid medium so that 1 ml of KMnO_4 = 1 ml of ammonium oxalate.

(b) Standard Am-oxalate solution : Dissolve .888 gm of am-oxalate in distilled water and make up to one litre (1 ml of this solution = .1 mg of O_2).

(c) Dilute sulphuric acid (1 : 3) : Add 100 ml of conc. c.p. sulphuric acid slowly into 300 ml of distilled water.

Procedure

Place 50 ml of the sample in a 250 ml conical flask and acidify with 5 ml dilute H_2SO_4 . Add 10 ml of standard KMnO_4 solution and keep it in a bath of boiling water for 30 minutes. Remove it and add 10 ml of am-oxalate solution. The pink colour of permanganate will disappear. Now add standard KMnO_4 solution drop by drop from a 10 ml graduated pipette till the colour just reappears. If the pink colour disappears while heating in water bath the procedure is to be repeated with 20 ml KMnO_4 solution or more if necessary.

No. of ml of KMnO_4 solution required X .1 X 20 = ppm O_2 consumed.

5.11 Calcium and magnesium

The total alkalinity of water gives a fair idea of its calcium and magnesium contents but these can be determined accurately by versenate method.

Reagents

(a) Standard sodium versenate : Dissolve 2.5 gm sodium versenate in 2 litres of distilled water. Add 13.5

ml N NaOH. Dilute to 2.5 litres and adjust by titration against standard Ca^{++} solution so that 1 ml = .1 mg Ca^{++} using Eriochrome Black T as indicator.

(b) Indicator for Ca + Mg : Add 1 gm Eriochrome Black T and 1 ml N Na_2CO_3 solution in 30 ml distilled water, mix together and make upto 100 ml with isopropyl alcohol.

(c) Indicator for Ca (solid) : .2 gm am-purpurate and 100 gm of NaCl are ground together in a mortar and kept dry.

(d) N NaOH solution

(e) Buffer solution : (i) add 40 gm borax in 800 ml distilled water (ii) 10 gm NaOH and 5 gm $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ in 100 ml distilled water. Mix the two solutions and dilute to one litre.

(f) Standard Ca^{++} solution (stock) : 125 gm pure calcium carbonate is added to 100 ml distilled water + 25 ml of .1 N HCl. The solution is made upto one litre, 1 ml of this solution = .05 mg of Ca^{++} .

Procedure

(i) Calcium alone; A standard end point is first prepared by diluting 10 ml of standard stock of Ca^{++} solution to 100 ml with distilled water adding 2 ml N NaOH and .2 gm calcium indicator to which 5 ml of versenate solution is slowly added from a pipette so that the indicator assumes the end point colour. 100 ml of the unknown sample is now treated in the same way except that the addition of versenate is continued until the tint of the unknown solution matches with that of the standard prepared.

No. of ml of versenate required = ppm of Ca^{++}

(ii) Calcium + Magnesium : 100 ml of the water sample is slightly acidified with .01 N HCl equivalent to the alkalinity and boiled. .5 ml of buffer solution is added and about 5 drops of Eriochrome Black T indicator. The sample is then titrated with standard versenate solution.

(No. of ml of versenate required for Ca + Mg - No. of ml of versenate required for Ca) X .61 = ppm of Mg

5.12 Silicate

Silicate in water can be determined easily by colorimetric methods using artificial standards.

Reagents

(a) Standard picric acid solution 108.8 mg/litre or Standard potassium chromate solution 284 mg/litre. Both are equivalent to .1 mg Si per ml.

(b) 10% Ammonium Molybdate solution

(c) 25% Sulphuric Acid (by volume)

Procedure

(i) Dilute 1 ml picric acid solution (a) to 100 ml with water to be tested in order that the water colour shall be the same in standard and sample. This standard is then equivalent to .001 mg Si per ml.

(ii) To 50 ml of ~~sample~~ in a Nessler tube add 2 ml Am-molybdate solution and .5 ml 25% H₂SO₄. Stir and allow to stand for 10 minutes.

(iii) Match the colour of the sample and the standard following the usual procedures.

No. of ml of standard X .001 X 20 = mg Si per litre

5.13 Specific conductivity : Specific conductivity offers a quick and convenient method for the determination of the dissolved salts in water collectively, the conductance of an electrolyte in solution being almost directly proportional to the ionic strength of that solution and the total conductivity is equal to the sum of the several conductivities resulting from the various ionisable salts present.

Procedure

Specific conductivity is generally determined by a Wheatstone bridge in which a variable resistance can be adjusted so that it is equal to the resistance of the unknown solution between two platinised electrodes of a standardised conductivity cell.

(1) Take .02 N KCl solution in a small beaker (2) Submerge the electrodes 1 cm below the surface of the solution (3) Establish the cell and fluid at a constant temperature (25°C) (4) Adjust the variable resistance (R) so that it is equal to the resistance of the cell which is generally given as .002765 at 25°C (5) Determine cell constant (C) from the relation $\frac{1}{R} \times C = K$ or $C = \frac{K}{1/R}$ (6) Repeat

the procedure with water sample instead of standard KCl solution to get the cell resistance R_1 . The specific conductivity of the water sample = $\frac{1}{R_1} \times C$ (in reciprocal ohms or mho). As these values are generally very small for natural waters, the results are expressed as 10^{-6} mhos at 25°C. The specific conductivity is reported in the following way : Eg.

140 X 10^{-6} mho at 25°C

6. PHYSICAL AND CHEMICAL ANALYSIS OF SOIL

6.1 Collection of soil samples

Collection of representative and composite samples of soil is as important as the analysis of sample itself. Any error during sampling (other than sampling variations) cannot be corrected at a later stage and even if the analysis is done very precisely, the results become erroneous because of error from bias. For collection of soil from lake bottoms, Ekman dredge for soft soils or Petersen grab for hard earth are generally employed.

The number of samples to be collected from an area depends upon the variability of the soil quality in the area studied. Minimum five samples should be collected from each contour of each sector of the reservoir. After collection the samples are mixed thoroughly to get a uniform composite samples, of at least 5 kg in weight. The samples are air dried in shade, ground to fine powder by gently pressing with a wooden hammer, strained through 2 mm sieve and again air dried. The percentage of moisture in the soil is determined by drying the soil in an oven at 103°C. Analysis is done with the air dried samples and results are expressed on oven dry basis.

6.2 Mechanical analysis

This gives an idea of the texture of the soil. It consists essentially of two operations viz. dispersion of the soil and grading the dispersed particles into size groups.

(i) Hydrometer method : A special type of hydrometer known as Bouyoucos hydrometer is used for this analysis.

Reagent

.5 N sodium oxalate solution

Procedure

Place 100 gm of air dry soil in a 500 ml conical flask, add 15 ml .5 N sodium oxalate and 200 ml distilled water and shake for one hour. Transfer the contents to a 1000 ml tall cylinder and make up the volume. Dip the hydrometer in the liquid after 5 minutes of sedimentation and the percentage of clay + silt is noted. The percentage of clay can be similarly determined by noting the hydrometer reading after 2 hours. As the hydrometer is graduated in gms per litre, its reading gives directly the percentage of suspended matter when 100 gm of soil is taken. Percentage of sand is obtained by deducting percentage of clay + silt from 100, similarly percentage of clay is subtracted from that of clay + silt to get the percentage of silt.

(ii) Gravimetric method

- (a) Hydrogen peroxide (6.0%)
- (b) N Hydrochloric acid
- (c) N Sodium hydroxide solution
- (d) Silver nitrate solution (5%)
- (e) Ammonium hydroxide solution
(concentrated)

Procedure

Take 20 gms of soil in a 400 ml beaker, add 35 ml H_2O_2 to it keeping the beaker in a water bath; when the reaction is over add more H_2O_2 till no more frothing takes place. Cool, add 50 ml N HCl and 200 ml distilled water to make the soil free of carbonates. Allow the content to stand for an hour with occasional stirring. Filter the soil and wash free of acid with hot water, tested by $AgNO_3$ solution. Transfer the soil to one litre beaker, add 8 ml N NaOH

solution and shake for 20 minutes in a mechanical shaker. Transfer the content to a 1000 ml tall cylinder, make up the volume and shake vigorously for one minute and allow to stand for 4 minutes. Lower a 20 ml pipette, 10 cm deep and suck out 20 ml of the content, dry it in a 50 ml beaker to a constant weight to get the wt of clay + silt. Repeat the operation after 6 hours to get the wt of clay alone. Now the percentage of sand, silt and clay are calculated in the same way as before.

To get the percentage of soluble matter in the soil the filtrate after acid treatment may be concentrated and iron and aluminium oxides precipitated by ammonia may be finally filtered, dried, ignited and weighed.

6.3 pH

(i) Electrometric method : This method gives direct reading and because of its accuracy and rapidity it is considered the best.

Procedure

Take 10 gm of soil in a 50 ml beaker and add 25 ml of glass distilled water (soil : water ratio as 1:2.5). The suspension is stirred at regular intervals for 20 minutes. Now the pH meter is set, electrodes are immersed into the samples and the pH determined. These pH meters are mostly direct readings recording pH in .1 unit intervals.

(ii) Colorimetric method : Colorimetric indicators are most useful for field testing kit and for soil testing laboratories. Though approximate, they give satisfactory results if properly and carefully used.

Reagents

- (1) Neutral Barium sulphate A.R. grade.
- (2) Indicator solutions (ref. sec. 5.4)

Procedure

Place a layer of neutral barium sulphate 1 cm thick in a 50 ml dry test tube, add 10 gm of air dry powdered soil and .25 ml of distilled water, shake well for 10 minutes and keep it for settling. Take 10 ml of clear aliquot and follow the same procedure as for pH of water.

6.4 Organic carbon

Organic carbon can be determined very rapidly with fair accuracy by the method described below.

Reagents

(a) Normal potassium dichromate solution: Exactly 49.04 gm of reagent grade $K_2Cr_2O_7$ is dissolved in distilled water and the solution is diluted to one litre.

(b) Normal Ferrous solution : Dissolve 278.0 gm of reagent grade $FeSO_4 \cdot 7H_2O$ or 392.13 gm of $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$ in distilled water, add 15 ml of conc. H_2SO_4 and make up the volume to one litre. This should be standardised against N $K_2Cr_2O_7$ so that 1 ml of Ferrous solution = 1 ml N $K_2Cr_2O_7$ solution.

(c) Diphenyl amine indicator : Dissolve .5 gm diphenylamine in 10 ml conc. H_2SO_4 and 20 ml distilled water.

(d) Phosphoric acid (85%)

(e) Concentrated sulphuric acid (sp. gr. 1.84)

Procedure

Place 1 gm of soil sample (.05 gm for peat, 2.0 gm for soils with less than 1% organic matter) in a 500 ml conical flask. Add exactly 10 ml of N $K_2Cr_2O_7$ and mix the two by swirling the flask. Then add 20 ml of conc. H_2SO_4 and mix by gentle rotation for one minute. Allow the mixture to stand for 30 minutes. Dilute with water to 200 ml and add 10 ml of 85% phosphoric acid. The excess dichromate is titrated with N $FeSO_4$ solution using 1 ml diphenylamine as indicator.

$$\frac{(10 - \text{No. of ml of } FeSO_4 \text{ solution required}) \times .003 \times 100}{100} = \text{organic carbon (\%)}$$

6.5 Total nitrogen

Total nitrogen may be estimated by Kjeldahl's method.

Reagents

(a) Concentrated sulphuric acid (sp.gr. 1.84)

(b) Salicylic acid (A.R.)

- (c) Sodium thiosulphate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$
- (d) 12 N NaOH: Dissolve 480 gm of sodium hydroxide pellets in distilled water and make up to one litre.
- (e) .1 N NaOH: Dissolve 4 gm of sodium hydroxide pellets in distilled water, make up to one litre and standardise against .1 N H_2SO_4 .
- (f) .1 N H_2SO_4 : Dilute 100 ml of N H_2SO_4 (stock solution) to one litre and standardise against .1 N Na_2CO_3 solution.
- (g) Potassium sulphate
- (h) Copper sulphate
- (i) Methyl red indicator
- (j) Phenolphthalein indicator

Procedure

Take 10 gm of air dry soil in a Kjeldahl's flask. Add 30 ml of conc. H_2SO_4 , one gm salicylic acid and keep in cold for half an hour. Then add 5 gm sodium thiosulphate and further keep it for half an hour. Add 1 gm of powdered copper sulphate and 10 gm of potassium sulphate and digest the mixture on a gentle flame in a fume cupboard. A clear blue solution indicates the completion of digestion. Cool and transfer with water to a ammonia distillation flask. Make it alkaline with excess of 12 N NaOH using phenolphthalein as indicator and distil off the ammonia collecting it in 25 ml of .1 N H_2SO_4 in a conical flask with a few drops of methyl red indicator. Collect about 150 ml of the distillate. Titrate the excess of .1 N H_2SO_4 with .1 N NaOH till the solution turns colourless.

(25 - No. of ml of NaOH required) X .0014 X 10 = total nitrogen (%).

6.6 Available nitrogen

Incubation method of estimating available nitrogen is a long and tedious process. Alkali - permanganate method, described below, may be used which gives fairly accurate results with much rapidity.

Reagents

(a) .02 N H₂SO₄ : Dilute 100 ml of .1 N H₂SO₄ of standard stock solution to 500 ml with distilled water.

(b) .02 N NaOH : Dilute 100 ml of .1 N NaOH of standard stock solution to 500 ml with distilled water.

(c) Methyl red indicator : Dissolve .1 gm of methyl red powder in 25 ml ethyl alcohol and make up the volume to 50 ml with distilled water.

(d) .38 percent KMnO₄ solution: Dissolve 3.8 gm of potassium permanganate crystals in distilled water and make up to one litre.

(e) 2.5 percent NaOH solution: Dissolve 25 gm of sodium hydroxide pellets in distilled water and make up to one litre.

Procedure

Place 10 gm of air dried powdered soil in a 500 ml Kjeldahl's distillation flask. Add 100 ml of .38% KMnO₄ solution and 100 ml of 2.5% NaOH solution, 2 ml of liquid paraffin and 10-20 glass beads and distil the mixture, collecting the distillate in a conical flask containing 20 ml of .02 N H₂SO₄ and a few drops of methyl red indicator. Collect about 75 ml of the distillate. Titrate the excess of .02 N H₂SO₄ with .02 N NaOH to a colourless end point.

(20 - No. of ml of .02 N NaOH) X 2.8 = Available nitrogen (mg/100 gm soil).

6.7 Available phosphorus

There are a number of methods for determining available phosphorus in soil which use different extractants. Of these Troug's method using .002 N H₂SO₄ as extractant is described below as it gives a good correlation with fish production.

Reagents

(a) .002 N H₂SO₄: Dilute 100 ml of standardised .02 N H₂SO₄ to one litre. Adjust the pH to 3.0 with Am-sulphate.

- (b) 50% H₂SO₄
- (c) 10% Am-molybdate solution
- (d) Acid - ammonium molybdate reagent
- (e) Stannous chloride solution
- (f) Standard phosphate solution

(1 ml = .01 mg P)

The methods of preparation of reagents (b) to (f) are the same as given for determination of phosphate in water.

Procedure

Place 1 gm of air dried powdered soil in a 250 ml bottle. Add 200 ml .002 N H₂SO₄ (pH adjusted to 3.0 with Am-sulphate), shake the mixture for 30 minutes in a mechanical shaker, keep it for 10 minutes and filter. Take 50 ml of the solution in a Nessler tube and determine its phosphate as for water.

No. of ml of standard X .01 X 4 X 100 = mg P/100 gm soil

6.8 Free calcium carbonate

This rapid method of determining HCl soluble calcium carbonate in the soil gives a fair idea about the lime content of the soil.

Reagents

- (a) .5 N HCl solution
- (b) .5 N NaOH solution
- (c) Bromothymol blue indicator

Procedure

Place 5 gm of air dried powdered soil in a 250 ml bottle and add 100 ml of .5 N HCl and shake for an hour. Allow to settle the suspension and pipette out 20 ml of supernatant liquid. Transfer to a small conical flask and add

six drops of bromo thymol blue indicator when a yellow colour develops. Titrate it with .5 N NaOH till it is just blue. Note the reading and carry out blank taking 20 ml of .5 N HCl in a flask and titrating in the same way.

$$(\text{Titre for blank} - \text{Titre for soil solution}) \times 2.5 = \% \text{CaCO}_3$$

7. METEOROLOGICAL OBSERVATIONS

The following monthly meteorological observations may be collected (available with reservoir authorities). Range and monthly averages may be shown for each item.

1. Rainfall (in mm)
2. Average wind speed (km/hr)
3. Air temperature ($^{\circ}\text{C}$)
 - a) Maximum temperature
 - b) Minimum temperature

8. DETERMINATION OF PRIMARY PRODUCTIVITY

8.1 By measuring carbon assimilation using radio isotope C^{14}

- (a) Selection of glass bottles of exactly same transparency

The bottles are cleaned thoroughly with acid-dichromate and after washing them repeatedly with distilled water, they are tested for equal transparency by placing a white paper with black parallel lines against the bottles. Those having exactly the same transparency are selected. One set of bottles are made dark either by painting with black paint or preferably wrapping them completely with black tape or placing them inside small black plastic bags.

- (b) Clamping of the glass stopper with a spring-clip arrangement

Care should be taken that under no circumstances, the content of the bottle containing radioactive material should leak through loose stoppers.

- (c) Construction of the float to suspend the bottles in water for 'in situ' experiments

The floats can be constructed with empty tin cans and wooden poles. While suspending the bottles care should be taken to avoid 'shading' of the experimental bottles by floats or by the bottles themselves. Exposure to equal light condition is highly essential for the experiment.

- (d) Collection of water from different depths, treatment with $\text{NaHCO}_3 - \text{Na}_2\text{CO}_3$ solution containing C^{14} and replacement at the same depths.

In order that the whole of the euphotic zone is covered, a predetermination of the light intensities at different depths is necessary.

Determination of Euphotic Zone

This is done by a light meter containing a photo electric cell connected to an ampere meter by a long water proof electrical wire. The mouth piece of the instrument which receives the incident light can be lowered to any desired depth by fixing it to a heavy frame and light intensity can be read from above in the ampere meter. It is calibrated in 'lux' with multiples of $\times 1$, $\times 10$ and can also read $\times 100$ by fixing a screen to the receiver. As the light intensities are plotted against the depth, it follows an exponential pattern. The depth is taken as the euphotic zone.

After determining the euphotic zone it is divided into a number of stretches preferably having planes at an interval of half meter. Now water samples are collected from each of these planes. These can be done by a Foerst type water sampler or a bottle sampler. The water is placed in experimental bottles, 3 light bottles and 2 dark bottles treated with diluted $\text{NaHCO}_3 - \text{Na}_2\text{CO}_3$ solution containing C^{14} are replaced at the same depths by tying them to the chords attached to the float. The C^{14} ampoules generally have a specific activity of about 4 μc which may be too strong. So a dilution to one-tenth the strength is done just before treatment. For this it is necessary to have dilution water having the same carbon - content (determined by alkalinity estimation and adjusting to desired strength). Nine ml of this dilution water is placed in a stoppered glass bottle,

the C^{14} ampoule is broken and the content poured into it, taking all pre-cautions that are necessary for handling radio active materials. It is mixed thoroughly and the desired quantity is taken out by an automatic pipette (In no case is sucking by mouth to be attempted). After treatment with C^{14} and replacement of the bottles to respective depths, they are incubated for five hours generally from 0700 hrs to 1200 hrs. The bottles are now taken out, immediately fixed with formalin and taken to laboratory for filtration. Filtration should be started immediately as otherwise the plankton may disintegrate and pass through filters. Filtering is done with 'mili-pore' filters H.A. type with detachable tower type glass or perspex filters having suction arrangement. It is preferable to have the filtration done under a uniform suction of .3 atmosphere. After washing with water of the same environment and finally with dilute hydrochloric acid, the filters with the residue are removed to desiccators and dried.

The filters thus processed may now be despatched to a Radio Tracer Laboratory for estimating the activity of C^{14} in them.

8.2 By measuring oxygen produced in photosynthesis using light and dark bottles.

This method is followed side by side with C^{14} technique for comparing results and can be followed in places where facilities for the more precise technique with C^{14} are not available. The experimental procedures are just the same as for C^{14} technique excepting that the treatment with C^{14} solution is omitted. Initial concentration of the D.O. of the dark and light bottles may be determined for an understanding of the respiration effect though they may not figure in the final calculation.

The method consists of taking water samples, containing a natural plankton population in glass bottles and exposing the bottles to light in the euphotic zone. In a parallel experiment a portion of the initial sample is held in a darkened bottle for the same length of time and at the same temperature as the illuminated sample. The initial O_2 content (IB) of the sample is determined by Winkler method. The difference between this concentration and the concentration found from water in the illuminated bottle after a suitable period of exposure (LB) is a measure of net evolution of O_2 due to photosynthesis (LB - IB). This difference is not

necessarily equal to the true net photosynthesis of the plants enclosed in the LB, as oxygen may have been consumed by both bacteria and animals in addition to the oxygen consumed by the respiration of the plant cells proper. It is more common to the Dark and Light bottle technique to measure gross photosynthesis. This is done by finding the difference between the initial oxygen content (I_B) of the water and the oxygen remaining in a dark bottle ($I_B - DB$). Such a difference (a loss of O_2 due to respiration) is assumed to be equal to the total respiration occurring in the illuminated bottle over the same period of time and thus if added to the net value obtained from the LB - IB above gives a measure of the gross photosynthesis from the relationship:

$$\begin{aligned} \text{Gross photosynthesis} &= \text{net } O_2 \text{ evolved} + O_2 \text{ used for} \\ &\quad \text{respiration} \\ &= \text{gain in LB} + \text{loss in DB} \\ &= (LB - DB) + (IB - DB) \\ &= LB - DB \end{aligned}$$

$$\text{Gross production} = \frac{LB - DB}{T \text{ (hrs)}} \times \frac{.375}{PQ(1.2)} \times 1000 \text{ mg C/M}^3/\text{hr}$$

$$\text{Net production} = \frac{LB - IB}{T \text{ (Hrs)}} \times \frac{.375}{PQ(1.2)} \times 1000 \text{ mg C/M}^3/\text{hr}$$

$$\text{Respiration} = \frac{IB - DB}{T \text{ (hrs)}} \times .375 \times RQ (1.0) \times 1000 \text{ mg C/M}^3/\text{hr}$$

PQ	= Photosynthetic coefficient
RQ	= Respiration coefficient

For making a representative study of primary productivity the selection of sampling points will be the same (vide sec. 4.1) as discussed under sampling procedures.

9. PLANKTON

In the quantitative evaluation of plankton, the important points that have to be borne in mind are 1) the exact amount of plankton-bearing water that has been sieved through and 2) correct estimation of plankton biomass as a whole in terms of volume/weight, 3) correct quantitative

estimation of phytoplankton biomass and its components and 4) correct estimation of biomass of zooplankton and its components.

9.1 Samplers to use

9.1.1 Kemmerer water sampler

This is by far best sampler for plankton collections. It provides precise volume of plankton-bearing water taken up for examination. The water can be taken from any depth precisely. Its limitations are that it provides small samples and consequently requires much time to get a good-sized sample. Use of Kemmerer sampler for depth-oriented collections, and bucket collections for surface samples are recommended. If small quantities of bolting silk (No. 25) can be obtained then small sized bolting silk nets may be made for reducing the volume of water taken in Kemmerer or other water samplers for analysis. Clarke and Bumpus type of samplers can be tried for horizontal hauls. This sampler is, however, useful only for zooplankton.

9.1.2 Net sampler

Plankton is generally collected by nets of truncated cone shape. Plankton, thus collected, is known as net plankton. The disadvantage in net sampling is that many smaller organisms, whatever be the grade of cloth used, escape. In spite of this, vertical hauls, which sieve a column of water, can be advantageously used, though at the cost of some precision, in the estimate of plankton biomass. Bolting silk is the best material for plankton nets and No. 25 standard grade may be used for making plankton nets. This has an aperture size of 0.064 mm (or 79 meshes per linear cm). Organdie is not suitable material for plankton nets because it is effective chiefly for zooplankton. Even if small quantities of bolting silk are available, making use of the same for filtering water samples collected by Kemmerer sampler and/or bucket to reduce the volume (concentration) for analysis is preferable to using an organdie-made net sampler. For work, giving emphasis on zooplankton, however, fine meshed organdie is satisfactory.

9.2 Design of plankton net

The net is of truncated cone shape. The upper diameter of the net which receives the brass ring is 30 cm. The lower diameter of net which receives the upper rim of the collecting bucket is 9.2 cm. The side length is 84 cm. The net may have canvas lining of 12.5 cm width at the top and 9 cm at the lower end. Where flow meter is used a larger net may be operated with the diameter of the upper brass ring being 50 cm, the lower ring diameter being 9 cm and side length 176 cm.

9.3 Estimation of volume of water sieved through plankton net

1. Take sounding for the depth for the spot/station chosen to take a vertical haul.
2. Give allowance (i.e. subtract) for the length of the net and collecting bucket.
3. Pull the net surface-wards at the rate of 0.3 m per second (approx.)
4. Transfer the sample from collecting bucket to graduated cylinder. Add 1 ml of formalin to every 20 ml of plankton and water.
5. Allow the plankton sample to settle for approximately 24 hours and note down its volume.
6. Express the plankton concentrate finally as ml per cubic metre in the following manner :

Settled plankton volume (in ml)

Area of the net mouth X length of haul (in metres)
(in sq.m.)

- Note :
1. The above estimate is only approximate. Many factors like speed of haul, size of mesh, age of net, clogging, spilling, current etc. interfere with correct estimation of column of water sieved. Where necessary a net coefficient may have to be computed on the basis of ratio of total plankton that would have occurred under optimal conditions, but for the above factors, to total plankton actually caught.

2. If there are no perceptible currents, then for horizontal surface sampling, a net sampler through a known distance at a slow speed can be used.
3. Where a flow meter has been used, a calibration curve should be plotted. In this curve, counts/second (velocity) should be plotted on the X - axis and counts/metre on the Y - axis. For experimental readings for purpose of calibration, towed distance may be kept constant at 25 m. For the purpose of tabulation of counts/metre for various velocities of the flow metre the data may be collected and computed as under:

Tow No. (Serial)	Time (Sec)	Flow metre Count units	Counts/Sec.	Metre/Sec.	Counts/Metre
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9.4 Quantitative estimation of total plankton

1. Settling volume: Allow sufficient time (24 hrs or more if necessary) for the plankton to settle in graduated cylinders and record its volume. This, however, includes variable quantities of interstitial water.
2. Displacement volume : (a) Record the volume of whole plankton sample water with plankters. (b) Filter off the plankton and determine the volume of plankton-free water (c) a-b gives the displacement volume. Record the data in ml.
3. Displacement weight : This can be expressed on the basis of above by assuming that the specific gravity of plankton is unity.

Dry plankton: Place centrifuged plankton concentrate in a platinum basin. Dry it in an electric oven maintaining the temperature at 60°C. The plankton dried to a constant weight represents dry plankton.

Dry organic matter: Transfer dry plankton, contained in the platinum basin, to an electric furnace maintaining temperature at 600°C. Leave the material in furnace for about 30 minutes. Subtract weight of furnace-incinerated sample from that of oven - dried condition of the same sample. Correction may be made for organic matter in solution in water by treating a 'blank' in the same manner as above.

9.4.1 Quantitative estimation of plankters

9.4.1.1 Direct census method

1. Take a microscope with suitable oculars and objectives.
2. Take Sedgewick-Rafter counting cell or prepare a similar one of area 50 mm X 20 mm and depth 1 mm showing mm square rulings.
3. Note down the volume of plankton concentrate.
4. Shake well the plankton concentrate and transfer one ml to the counting cell and cover it with a rectangular cover glass.
5. Count plankters specieswise, genera-wise or group-wise in 10 squares and find out the average. Ten counting units must be taken at random. Where counting units, randomly chosen, show no plankters they may be counted as zero and included in the computation of average number of plankters per counting unit of 1 cu mm capacity. The numbers of plankters in terms of species/genera/group per litre of original reservoir water can be computed using the formula:

$$n_i = \frac{(a \cdot 1000) \cdot c}{l} \quad \text{where}$$

n_i = numbers of plankters (in terms of species or genera or group per litre of original water)

a = the mean number of plankters per counting unit of one mm²

c = volume of concentrated plankton in ml

l = volume of original reservoir water in litres

Larger plankters, however, can be counted through the entire counting cell of 1 ml capacity. In that case a separate computation for large plankters in terms of species/genera/group is required. The number of larger plankters per litre of original reservoir water is :

$$n_i = \frac{Wc}{l} \quad \text{where}$$

n_i = the number of large plankters (in terms of species/genera/group) per litre of original water

w = the number of larger plankters in the entire counting cell of 1 ml capacity

c = volume of concentrated plankton in ml

l = volume of original reservoir water in litres.

For total count add all small and large plankters enumerated species/genera/group wise.

- Note :
- a) Exclude consideration of debris, fragments of plankters and other accidental inclusion.
 - b) Count each filament as one plankter. Better still, if these filaments can be expressed in units of 100 microns of length. Count each colonial form as a separate entity. Better, if they are expressed in terms of certain standard medium-sized colonies using whipple micrometer.

9.4.1.2 Induction of volume to plankters

For determining the volume of planktonic components it is essential to prepare tables showing the numbers of zooplankters (say, Daphnia, Diaptomus etc.) in a millilitre of settled volume. Such numbers/ml must be prepared size-wise. For example:

Class Interval in mm, of size groups.	Nos. of Daphnia per ml of settled volume.	Nos. of Diaptomus per ml of settled volume
0.30 - 0.40		
0.50 - 0.60		
0.70 - 0.80		
0.90 - 1.00		
1.10 - 1.20		

To determine the volume of zooplankters species-wise the following procedure may be followed:

1. The number of organisms of a particular species in sample may be computed from data from direct census method.
2. Measure the individual lengths of organisms by ocular micrometer and determine their average lengths. Find out the class interval/class intervals they fall into.
3. From the already prepared tables find out the number of organisms per ml per the particular class interval or class intervals for the particular species.
4. Divide the numbers in item one by numbers in item three. The quotient is the estimated volume of organisms in the sample in ml.

For the evaluation of volume of algae a table should be prepared showing the number of individuals or colonies per ml. This would enable sample counts to be converted into volume.

10. LARGER AQUATIC PLANTS

10.1 Quadrat sampler

To study the larger aquatic plants (submerged and emergent plants), prepare quadrat frame or iron grid of 1 sq m dimension (side 1 metre x 1 metre). It should be provided with a depth of 30 cm by metal sheets at the base. It may be given additional depth of suitable material according to requirements.

This can be easily operated in shallow areas upto 2 m depth and the enclosed vegetation collected.

10.2 Collection and computation

1. The material collected may be segregated species-wise, genera-wise or group-wise.
2. Drain out the water completely from the plant material.

3. weigh the material as per their qualitative identity. Also add up the weight of individual groupings to get the total weight.
4. Find out the ~~transverse~~ area of the quadrat frame, in the present case 1 sq metre.
5. Compute the biomass of the aquatic plants per sq. metre as indicated below:

$$W = \frac{w}{ao} \text{ where,}$$

W = weight of larger aquatic plants above 1 sq. m of bottom surface.

w = weight of larger aquatic plants per composite sample which may contain one or more operations

O = number of operations

a = area of the quadrat frame in sq.m.

(Note : Weight of larger aquatic plants may be expressed in kg)

11. BOTTOM BIOTA

11.1 Bottom sampler

Ekman dredge is best suited as a sampler for bottom biota for soft bottoms. Two sizes of this sampler are available namely 15.2 x 15.2 cm and 22.9 x 22.9 cm. The former is more convenient from the point of view of sampling. Where, however, the bottom is hard, Peterson grab with an enclosure area of about 0.08 sq m may be used.

11.2 Collection procedure

1. Collect samples by Ekman dredge from randomly chosen stations.
2. Each sample may be transferred to suitable containers like enamel buckets or other larger sized containers.
3. Take sieve No. 40 which will retain only macro-organisms.

4. Take suitable quantity of dredged material from the bucket and place it in sieve. Wash it with liberal quantities of tap water or water from other source.
5. Transfer the residue (macro-organisms) into a wide-mouthed bottle. Repeat the same procedure for other parts of sample.
6. Preserve the material in 10% formalin, if detailed analysis has to be done at a later date.

(Note: Should studies cover micro-organisms as well, use sieve No. 100 or other finer grades)

11.3 Quantitative evaluations and computations

(a) Count method

1. Transfer small portions of screenings into petri dishes or shallow porcelain dishes.
2. Segregate the organisms into species, genera or groups according to the nature of the investigations.
3. Count them per qualitative identity under one or more of the above heads.
4. Compute for each individual group or for all groups the number of macro-organisms per square metre, which can be done as follows:

$$N = \frac{n}{ah} \quad \text{where,}$$

N = number of macro-organisms in 1 sq m

n = number of macro-organisms per sampled area

a = area of Ekman dredge in sq m

h = number of hauls

(b) Volumetric method

1. Place a group of organisms upon filter paper and retain them until the moisture is removed. Repeat for other groups.

2. They may then be transferred to a test tube of known volume calibrated for 1 and 2 ml. According to size of the sample, water is then added from a burette upto 1 ml or 2 ml marks.
3. Subtract the amount of water dropped from the burette, from the test tube reading which gives the volume of bottom organisms in the test tube.
4. Compute the volume of animals per sq m either for individual groups or for all animals, by the formula:

$$V = \frac{v}{a h}$$

V = volume in ml of macro-organisms above 1 sq m of bottom surface

v = ~~volume of macro-organisms~~ volume of macro-organisms per sample (containing one or more hauls)

a = transverse area of Ekman dredge to be expressed in sq m

h = number of hauls constituting a sample

(c) Gravimetric method

1. Place a group of organisms upon filter paper and retain them until the moist sheen is removed. Repeat for other groups.
2. Weigh them in a balance of appropriate sensibility. The weight recorded represents the wet weight.
3. Dry the above to a constant weight to get dry weight.

(Note: Exclude the shell weight of molluscs).

12. OBSERVATIONS ON EXISTING FISHING OPERATIONS, IF ANY, IN RESERVOIRS

'Untimbered' reservoirs with uncleared tree stumps and other impediments provide, as is well known, serious difficulties in fishing and cause, in the process, considerable element of 'bias' in the sampling for size frequency and fish population. The popular gears, namely, drift nets and set gill nets are inevitably size-selective. The shore seines are topographically restricted in operation, but if fine meshed, are less selective and relatively less biased. Long line fishing with different sized hooks are size-selective and so are traps. Fishing operations should also take into account immigration and emigration of fishes in reservoirs. All the above stated factors render evaluations of abundance, conventionally estimated on the basis of 'catch per unit of effort' rather unreal. Great caution is indicated in making use of such estimates of catch per unit of effort for the evaluation of population size or mortality.

12.1 Total catch

Follow the sampling procedure given under (4.1 e) for estimating the yield statistics of the reservoir. Choose the days of sampling randomly. Consult random number tables available in any standard book on Statistics for the above purpose.

1. Docket the sampled days' landings species-wise. Uneconomic species can be clubbed under a 'miscellaneous head' but basic data sheets should indicate their species composition as well.
2. Compute the species-wise monthly landings on the basis of sampled days. Give allowance for non-fishing days.
3. Compute the annual total landings and species-wise landing on the basis of monthly landings.

(Note: Where sectoral catches of the reservoir can be estimated it is desirable to sample landings sectorwise, and compute monthly and annual landings for sectors. These figures can be pooled for total yield and species-wise yield for reservoirs as a whole).

12.2 Fishing effort

In capture fisheries studies, information on fishing effort plays an important role and its estimation should fulfil certain conditions which are :

1. the mortality generated in the stock due to fishing operations should be proportional to fishing effort and
2. the catch per unit of effort should be proportional to the abundance of the stock.

Fishing effort for any single unit of gear may be expressed as the product of the size of the gear and duration of fishing or number of hauls. The following information has to be collected.

1. length of the net
2. length of each piece (may be taken as unit)
3. number of hooks (in line fishing)
4. total time spent of fishing
5. number of hauls
6. duration of each haul

(Note: Mere mention of number of fishermen, number of boats, number of landings and such general numerical representation of fishing effort will not be useful. They may or may not represent the actual fishing effort. However, such information may be collected in lieu of or along with the above data and in certain situations can be used as substitutes).

12.3 Fishing intensity

Fishing intensity is reflected by fishing effort per unit area. When two or more types of gears are used in an area they should be adjusted to a common denominator in terms of the dominant gear. For each increase in the adjusted unit there is a corresponding proportional increase in instantaneous rate of fishing.

12.4 Catch per unit of effort

The catch of fish in numbers or in weight taken by a defined unit of fishing effort represents catch per unit of effort. It is also variously termed as fishing success, availability etc.

12.5 Mesh selectivity

Meshes of gear exhibit selective properties with reference to sizes of fish caught. For each mesh size there is, what is known as a "50% point" of the size of fish escaping or retained by that mesh. The chances of a fish escaping or being retained depend on its girth. Girth itself is directly proportional to the length of the fish. It is evident then that length of the fish at the 50% point is directly proportional to mesh size. The following information may be collected to study mesh selectivity.

1. Mesh range, if any, and average mesh size in mm or cm. Express mesh in terms of bar length.
2. Length of the fish and corresponding
 - a) natural girth (body girth) in mm (i.e. the part of fish where its girth is greatest).
 - b) constricted girth i.e. the encompassing noose (thread or tape) constricting the part of the fish where its girth is greatest.
 - c) smallest recorded natural girth for particular lengths.

- (Note:
1. In addition to the body girth take also the gill girth and the girth in between (i.e. between body girth and gill girth). Take also their corresponding constricted girth.
 2. The regression line of length on girth can be fitted by the method of least squares.
 3. To determine '50% point' in drag nets with well defined cod end a close meaned covering should be provided surrounding the cod end to collect the escaping fish.

4. Where the cod end shows mesh variations average mesh size should be determined.

13 EXPERIMENTAL FISHING IN RESERVOIRS

Drift nets and bottom set gill nets are known to be quite effective gears in Indian reservoirs and it is desirable that some experimental nets of the above types are constructed and operated in all the reservoirs/ can be examined from two angles, namely, 1) their catching capacities from commercial view point and 2) their usefulness as sampling gear for fish population studies. It is proposed to use drift nets of the meshes 50, 63, 75, 88, 100, 113 and 125 mm bar, bottom set gill nets of 37 and 50 mm bar and shore seine of mesh bar 7-25 mm. Rangoon nets and Unduvalai of the type used in Mettur Dam will also be used. Gulbadamov (1962) working in Indian reservoirs has already experimented with a few designs but could test them only for a very short period. There is urgent necessity that these are tested for their efficacy on a much larger scale covering a number of reservoirs and for a longer time. The information collected must be properly docketed on 'data sheets' and finally analysed with reference to the above two aspects. Since the material used for webbing and line is terylene continuous multifilament twines it is desirable to indicate the twines numbering by Denier system and is as follows (given by Gulbadamov):

Denier system	Commercial No.	Diameter mm/	Breaking strength (kg)
250/3	1	0.38	5
250/2/3	2	0.50	10
250/3/3	3	0.63	15
250/4/3	4	0.78	20
250/5/3	5	0.85	25
250/6/3	6	0.93	30
250/8/3	8	1.30	40
250/16/3/3	16	3.00	180

The hanging of webbing, given below, for each of the nets may be computed as :

/taken up for comparative studies so that their usefulness

$$\% \text{ of hanging} = \frac{\text{length of line} \times 100}{\text{length of stretched webbing}}$$

13.1 Drift nets

Drift nets of 50, 63, 75, 88, 100, 113 and 125 mm bar are to be used. Their specifications are given below:

I. Specification for Drift nets of the 50 mm bar mesh size

Webbing

- a) Hand braided with double knot, selvedge of 2 meshes width all round
- b) Length 145 m stretched, 72.5 m hung
- c) Depth 6.2 m stretched, 5.5 m hung

Rigging

- a) Hanging coefficient 0.5
- b) Distance between floats 1.5 m
- c) Distance between sinkers 2.5 m

Material

The material for webbing and lines is terylene continuous multifilament. Twine for main webbing 250/3, for selvedge 250/3/3, the hanging twine (to float line and lead line) 250/4/3 and framing lines 250/16/3/3. The breast lines are simply roved through the last row of meshes. Distance between floats 1.5 m and between sinkers 2.5 m. Floats light wood cylindrical shape with length 100 mm, diameter 30 mm and hole 5 mm, sinkers - burned clay, oval shaped, length 79 mm, diameter 35 mm and weight 30 gm.

II. Specifications for Drift net of 63 mm bar mesh size

Webbing

- a) Hand braided, selvedge of 1.5 meshes width all round
- b) Length 140 m stretched, 70 m hung
- c) Depth 7.3 m stretched, 6.4 m hung.

Rigging

- a) Hanging technique same as described for 50 mm bar mesh size
- b) Distance between floats 7.5 m
- c) Distance between sinkers 2.5 m

Material

Webbing and line of terylene continuous multifilament; floats, spherical plastic floats, diameter 80 mm; sinkers, burned clay, oval shaped and of length 80 mm and weight 48 gm.

III. Specifications for drift net of 75 mm bar mesh size

Webbing

- a) Hand braided, selvedge of 2 meshes width all round
- b) Length 100 m stretched, 50 m hung
- c) Depth 6.75 m stretched, 6.10 m hung

Rigging

- a) Hanging coefficient 0.5
- b) Distance between floats 1 m
- c) Distance between sinkers 5 m

Material

Webbing and lines of terylene continuous multifilament; twines for webbing 250/2/3, for selvedge 250/4/3, for framing lines 250/16/3/3. Floats and sinkers as in 50 mm bar mesh size drift net above.

IV. Specifications for drift net of 88 mm bar mesh size

Webbing

- a) Hand braided, selvedge of 2 meshes width all round
- b) Length 100 m stretched, 50 m hung
- c) Depth 6.8 m stretched, 6.0 m hung

Rigging

- a) Hanging coefficient 0.5
- b) Distance between floats 7 m
- c) No sinkers

Material

Webbing and lines of terylene continuous multifilament. Twine for main webbing 250/3/3, for selvedge 250/4/3. The webbing was hung to float line and leadline of terylene 250/16/3/3 by terylene hanging twine. Floats, spherical and plastic and of diameter 80 mm.

V. Specifications for drift net 100 mm bar mesh size

Same as for drift net of 88 mm bar mesh size excepting change in mesh size.

VI. Specifications for drift net of 113 mm bar mesh size

Webbing

- a) Hand braided with a selvedge of 1/2 meshes width all round.
- b) Length 80 m stretched, 40 m hung
- c) Depth 6.8 m stretched, 6.2 m hung

Rigging

- a) Hanging coefficient 0.5
- b) Distance between floats 8 m
- c) No sinkers

Material

Webbing and lines of terylene continuous multifilament. Webbing twine 250/3/3 and 250/4/3, for selvedge 250/8/3 and framing line 250/16/3/3. Floats, spherical and plastic and of 80 mm diameter.

VII. Specification for drift net of 125 mm bar mesh size

Same as for drift net of 113 mm bar mesh size excepting for change in mesh size.

13.2 Bottom set gill nets

Bottom set gill nets of 37 and 50 mm bar are to be used. Their specifications are given below:

I. Specification for bottom set gill nets of 37 mm bar mesh size

Webbing

- a) Hand braided with selvedge 1 1/2 meshes width
- b) Length 150 m stretched, 75 m hung
- c) Depth 2.3 m stretched, 2.0 m hung

Rigging

- a) The webbing was hung to float line and lead line with a coefficient of 0.5
- b) Distance between floats 7.5 m
- c) Distance between sinkers 5 m

Material

Webbing and lines of terylene continuous multifilament. Webbing twine 250/3, for selvedge 250/2/3 and framing-lines 250/16/3/3. Floats, oval, plastic of 165 mm length and 55 mm diameter with a 16 mm hole. Large pear shaped plastic floats are attached to the ends of net with strops; sinkers, burned clay of length 85 mm and weight 50 gm.

II. Specifications of bottom set gill nets of 50 mm bar mesh size

Same as bottom set gill net of 37 mm bar mesh size

13.3 Shore seine

Specifications for shore -seine

The details given here for shore-seine are from models used in Tungabhadra Dam and found effective for medium and small fishes. They may be tried in other reservoirs to test their efficiency.

The net length is 100 m but with varying width, narrowest at ends ($3\frac{1}{2}$ m) and largest at centre ($6\frac{1}{2}$ m). The central part of the net, 40 m in length, has the smallest mesh 7 mm (bar). The mesh size increases towards the end through 12 mm, 20mm and 25 mm. There is a selvedge of 25 mm bar for two meshes inwards followed by 15 mm bar selvedge for 0.5 m all round the periphery of webbing. The net is constructed with cotton twines of 5 to 8 counts. 3.5 cm thick coir repes are tied as head and foot ropes and continued as pulling ropes for 100 m on either side. Wooden floats 70-75 in number, are tied to the head rope at intervals of 1 to 2 m. No sinkers are used for this net.

13.4 Data to be recorded on experimental fishing

As shown under 12.2

Note : Multimeshed gill nets can be constructed by joining together the gill net pieces of different bar meshes. These can be joined together in various permutations. If n pieces of gill-nets each of different mesh are piece together in a multimeshed gill net the permutations of n pieces (i.e. their order of arrangement) taken all together are

$$n (n-1) (n-2) \dots 3.2.1 = \underline{n!}$$

The catch composition of these multimeshed gill nets should be studied for their possible use in population census.

14. FISHERY BIOLOGY

14.1 Age and growth in fishes

The age of fishes is determined by any of the following methods :

- a) Length frequency
- b) Marking experiments
- c) Using hard parts of fish

a) Length frequency

The determination of age from length frequency is based on the following principles:

1. The length frequency of fishes of each age group, has a 'normal' distribution provided the spawning is restricted.
2. Where a fish (species) has a number of age groups and when the length frequency of such a fish is drawn, it results in a poly-modal curve, the modes of which represent the mean sizes of constituent age groups.

Data requirement

1. A random sample of length measurements
2. Samples at regular intervals
3. Gear type
4. Mesh size (bar measurement)

- Note :
- (i) Divide the length measurements of samples into suitable class intervals. Show the class marks on the x - axis and frequency (or % frequency) on the y - axis. Study the compound curve and isolate the constituent modes.
 - (ii) Item two will give information on growth per unit time of constituent age groups.
 - (iii) Item three and four will indicate any bias in size composition resulting from the mode of capture and mesh size.
 - (iv) Random samples from non selective gears should be used for age and growth study.

(b) Marking experiments

Here marked or tagged fish of known age are liberated and when recovered after a length of time given a direct estimation of age.

Note: (i) Use steamer tags a description of which is given elsewhere in this manual (ii) keep a record of dates, place and sizes at release of tagged fish and their recovery.

(c) Hard parts as basis of age determination

Layers deposited annually or at appropriate but constant intervals in the hard parts of fish provide clues to the determination of ages in fishes. Scale, otolith, spine, vertebra and other bony structures are used for this purpose. However, these must satisfy the following conditions:

1. that their growth is proportional to the growth of fish
2. that growth checks represented by 'rings' are formed yearly and at specified period
3. and in the case of scales, their number and identity remain constant for the fish studied.

Where hard parts are used for age determination they must always be accompanied by the following information :

1. Date of collection
2. Length of fish
3. Weight of fish
4. Sex of fish
5. Stage of maturity
6. Water temperature

(Note: (i) In the case of spiny-rayed fish, collect the scale samples at the end of pectoral fin;

- (ii) In the case of soft-rayed fish, collect the scale samples between lateral line and dorsal fin;
- (iii) In the case of otoliths, use sagitta;
- (iv) In the case of centra of vertebrae, use those of the first five prehaemals or that of the 5th vertebra
- (v) In fishes with scales collect scale samples and keep them in specially prepared scale envelopes, after properly washing them. On these scale envelopes write down information 1-6 given above. In tagging experiments scale samples should be collected both at the time of release and recovery).

14.2 Length-weight relationship

Weight in fishes may be considered a function of length and the formula linking these two is as follows:

$$W = c L^n \text{ or}$$

$$\log W = \log c + n \log L$$

(W = weight; L = length, c = multiplying constant and n = exponent of length)

Date requirement and computation :

1. Collect paired lengths and weights covering all size groups
2. Find out the log values of paired lengths and weights
3. Multiply the log L and log W for each of the paired values
4. Square the log of each of the lengths
5. Summate the columns
6. Note down the number of paired observations (N)
7. Calculate 'c' and 'n' as follows:

$$\text{Log } c = \frac{\sum \log W \cdot \sum (\log L)^2 - \sum \log L \cdot (\sum \log L \cdot \log W)}{N \cdot \sum (\log L)^2 - (\sum \log L)^2}$$

$$n = \frac{\sum \log W - N \log c}{\sum \log L}$$

(Note : Find out the length-weight relationship of all commercial fishes in reservoirs. Where the fish maintains the same shape and its specific gravity constant the weight increases as the cube of length).

14.3 Index of condition

The 'condition' of the fish is reflected by its plumpness. The plumpness of fish, in its turn, reflects the feeding conditions in the environment, in the present case, reservoirs. A numerical representation providing an index of condition of fish is, therefore, desirable and is especially useful for comparative studies of the well-being of fish in different reservoirs. The index can be constructed as follows:

$$K = \frac{\text{Weight} \times 10^5}{(\text{Length})^3} \text{ where,}$$

K = coefficient of condition

(Wt. may be given in gms and length in mm)

For the above study the data required are randomly sampled length measurements and their corresponding weights covering all seasons.

(Note : In comparative studies of well-being of fish in reservoirs the interpretations should take into consideration (i) that the index of condition for a species varies with seasons and (ii) a sparse population will give an artificial high index of condition).

14.4 Scale of maturity

(for field examination of gonads)

Stage	I. <u>Virgin</u>	Very small sexual organs close to vertebral column; testis and ovary transparent, colourless to gray eggs invisible to the naked eye.
Stage	II. <u>Maturing virgin & recovering spent</u>	Testis and ovary translucent, gray red. Length half or slightly more than half the length of the ventral cavity. Single eggs - small and unyolked - can be seen with magnifying glass. Nucleus clearly visible.
Stage	III. <u>Developing</u>	Testis and ovaries opaque, reddish with blood capillaries. Occupy about half of ventral cavity. Eggs visible to the naked eye as whitish granules. Formation of yolk granules started. Nucleus slightly visible.
Stage	IV. <u>Developed</u>	Testis reddish white. No milt drops appear under pressure. Ovary orange reddish. Eggs clearly discernible, opaque, yolked. Testis and ovary occupy about 2/3 ventral cavity. Nucleus not visible.
Stage	V. <u>Gravid</u>	Sexual organs filling ventral cavity. Testis white, drops of milt fall with pressure. Eggs completely round, some already translucent and ripe.
Stage	VI. <u>Spawning</u>	Roe and milt run with slight pressure. Most eggs translucent with few opaque eggs left in the ovary.
Stage	VII. <u>Spent</u>	Not yet fully empty. No opaque eggs left in ovary.
Stage	VIII. <u>Resting</u>	Testis and ovary empty, red. A few eggs in the state of reabsorption.

(Note : Doubtful cases may be indicated by referring to two stages e.g. IV/V, II/III etc.)

14.5 Fecundity

Fecundity for a mature fish denotes the number of eggs produced per spawning season. It is estimated on the basis of mature eggs in the ovary and computed as follows:

1. Measure the settling or the displacement volume of both ovaries. Or take the weight of both ovaries in a balance of appropriate sensibility.
2. Dissect out a sample containing, say, 3 sections from different parts of the ovary (anterior, middle and posterior) and find out the volume or weight as indicated above.
3. Count the number of eggs in the sample, namely, the dissected out sections.
4. Estimate the total number of eggs :

$$\text{No. of eggs} = \frac{\begin{array}{l} \text{Total vol.} \\ \text{(or wt) of} \end{array} \times \begin{array}{l} \text{No. of counted eggs in} \\ \text{sample} \end{array}}{\text{Vol. (or wt) of sampled ovary}}$$

To separate the eggs from the ovary, use Gilson's solution which is prepared as under :

Nitric acid (80%)	15 ml
Glacial acetic acid	9 ml
Alcohol (60%)	100 ml
Distilled water	880 ml
Mercuric chloride (sublimate)	20 gm

(Note : Fecundity varies approximately as the weight of fish and as the cube of the length of fish each with a multiplying constant).

Data requirement for correlation of fecundity with length and weight

1. Fecundity (No. of mature eggs)
2. Length of the fish (mm)
3. Weight of the fish (gm)

14.6 Food of fishes

Growth and 'condition' of fish are tied up with availability and proper utilisation of fish food resources. A comparative study of gut contents of fishes would indicate the extent of 'competition' among them, their food preferences and environmental suitability or otherwise. Broadly the gut contents may be analysed numerically, volumetrically and gravimetrically. The choice of method will depend upon the type of feed of the fish. Volumetric and occurrence methods should be adopted in all cases, Based on these methods an index known as 'index of preponderance' (14.6.1e) should be worked out.

14.6.1 Procedure for quantitative methods

(a) Volumetric

1. Determine the volume of gut contents in sample by water displacement method.
2. Sort the sample to kinds of items (species or larger groups).
3. Obtain volume of each kind of food item in the sample.
4. Compute percentage for each kind of food item that it forms in the total volume of food in the series.

(b) Gravimetric

1. Obtain weight of gut contents in sample.
2. Sort the sample to kinds of items (species or larger groups per requirement).
3. Obtain weight of each kind of food item in the sample.
4. Compute percentage which each kind of food item forms in the total weight of gut contents in the series.

(c) Numerical

1. Sort the gut contents to kinds of items (species or large groups)
2. Count the individuals for each kind of food item in the sample
3. Summate each of them in the series
4. Compute numerical % of each item in the gross total

(Note : In the case of volumetric can gravimetric analysis a short-out method can be followed. Pool monthwise the fishes class-interval wise and indicate the analysed data in terms of average size of the class interval. In the case of numerical analysis take from the class-interval-wise determined volume of gut contents a few samples and determine the counts of each of the organisms. Compute the numbers per qualitative identity for the total volume.

(d) Occurrence methodMethod I

1. Count the number of fish in which each food item occurs
2. Express the above as percentage of the total number of fish examined

Method II

1. Summate the occurrences of each food item.
2. Find the % of individual occurrences (i.e. kind of items)

(e) Index of preponderance

The volumetric, gravimetric and numerical methods of analysis emphasise only the quantitative aspects of gut contents while 'occurrence' method indicate only the

frequency of occurrence of food items. These methods individually are not suited for grading the food elements unless they are combined into an index. Index of preponderance is such a composite measure which takes both of quantity and occurrence into consideration simultaneously.

If v_i and o_i are the volume and occurrence index of food item i (as indicated by their percentages) the combined index (I_i) for food i may be presented as follows:

$$I_i = \frac{v_i \quad o_i}{v_i \quad o_i} \times 100$$

(Note : The state of digestion of gut contents indicates how far the food items in question are used in metabolism. For this purpose rectal contents should also be studied and undigested food items recorded).

(f) Forage ratio

This provides an index as to how the bottom biota is consumed by fishes. Forage ratio represents the ratio of the percent that a given species/genus/group of organisms forms in the total stomach contents of fish sample to the percent that the same kind of organisms constitutes of the total population of food organisms in the bottom sample.

Collect information as under :

1. Take random samples of bottom biota seasonally and find out the percentage of the constituent organisms.
2. Pool the individually analysed fish stomachs seasonwise and find out the percentage of constituent organisms.
3. Divide (2) by (1) to get the forage ratio.

(Note : Forage ratio of 1 indicates random selection of food items from the environment. A ratio less than 1 indicates or avoidance of the particular food item or they are otherwise unavailable. A ratio greater than 1 indicates that the food item in question is actively preferred or chosen).

15. POPULATION DYNAMICS OF FISHES

In the studies of population dynamics of exploited fish stocks, four primary parameters enter into computation. They are (i) recruitment (ii) growth (iii) natural mortality and (iv) fishing mortality. These are best studied in unit fisheries.

15.1 Unity fishery

It is desirable to define the relation between 'fished' (fish population) and 'fishing' as in it rests the evaluation of various population parameters. The fish population and the fishery based on it should form a unit such that their interaction can be interpreted. If there is immigration or emigration of fish of permanent character, these should be noted and given due consideration in the interpretation of abundance of year classes. Collect information on the following which will help in assessing the unit basis of the fishery:

1. Observations on the spatial distribution of fish
2. Observations on spawning and feeding areas
3. Observation on catch and effort over a period of years.
4. Abundance of year classes

15.2 Tagging and fin clipping as aids to study of various parameters

Object of tagging

There is no single experiment that given more information than tagging in fisheries investigations. Age, growth, rate of exploitation, survival, population size and migration are among the many on which it throws light.

15.2.1 Tagging

In India two types of tags have been used, namely, Petersen type and streamer tag of which the latter was more successful. Rectangular pieces of coloured celluloid of dimension 22 mm x 6 mm (of thickness about 1 mm) were used in Chilka lake. Numbers were engraved on this by special tools. A streamer tag of vinyl plastic of dimension 35 mm x 12 mm (and about 0.2 mm thickness) has been used for Hilsa in Hooghly and other parts of River Ganga. The necessary legends for these tags were written with Vinyl sampling Black Ink 104 N5A4 manufactured by California Ink company, U.S.A. Recently Central Institute of Fisheries Education, Bombay used plastic steamer type tags of which numbers were machine-punched. Streamer plastic tags can be used in reservoirs with advantage as they are found to harm least the fish tagged. Nylon twine may be used to tie the tag to body musculature behind the dorsal fin and the loose ends heat-sealed. Straight, semicircular or tip-bent needles may be used to pierce body musculature of fish. The tip-bent needle seems best suited among them. Nylon twine and needle may be dipped in a mild solution of Acriflavin as a precaution against the puncture getting septic.

15.2.2 Fin clipping

Fin clipping is quite suitable for juveniles and fingerlings (4-15 cm). Fins must be deeply excised close to the base, as otherwise, there is a possibility of regeneration. They are suitable only for short term studies. It is necessary to keep a small sample, say, of 500 clipped fingerlings in a small rearing pond to study the fin regeneration and mortality if any. Where there is regeneration and mortality the percentage for each of them should be individually computed for corrections in the estimation of population parameters.

15.3 Estimation of population size and other parameters

The marking experiments discussed have may cover one or more years. If one year is taken the year may be partitioned appropriately into two or more periods according to requirement. Marking should be completed within a short period as far as possible.

1. Note down the number of fish tagged (M)
2. Note down the recaptures in the first and successive periods: R_1, R_2, R_3 etc. The survival rate/interval is estimated as :

$$s = \frac{R_2 + R_3 + R_4 \dots + R_n}{R_1 + R_2 + R_3 \dots + R_{n-1}}$$

(Note : the survival rate is assumed constant for in-between periods considered).

The mortality rate/interval is :

$$a = 1 - s$$

The rate of exploitation is :

$$u = \frac{R_2 + R_3 + R_4 \dots R_n}{sM (1 + s + s^2 + s^3 + s^{n-2})}$$

Expectation of natural death/period is :

$$v = a - u$$

The rate of fishing is :

$$P = \frac{u i}{a} \text{ where,}$$

i = instantaneous total mortality coefficient

Estimation of population size :

$$N = \frac{M C}{R} \text{ where,}$$

C = the catch or sample taken for census on the first time interval

N = the size of population at time of marking

In order to eliminate the effects of variable recruitment the tagging experiment discussed above may be studied year-class-wise. The same tagging experiment is also suitable for estimation of survival rate of fingerlings to be stocked in reservoirs.

(Note : 1) If population is required to be assessed during a short-period the following method can be followed : A specified number of marked fish (M) should be released into the reservoir. Record the number of marked fish recovered (R) during a particular time interval (say, a year or a season)

and the total number of fish (C) captured during the same time interval. Then R/M represents rate of exploitation and MC/R the size of the population at the time of marking.

- 2) Population size can also be estimated by catch per unit of effort. If catch per unit of effort is plotted on the Y - axis and cumulative catch on the X - axis the plots give a straight line. The X - axis intercept gives an estimate of the original population size.

15.4 Recruitment

Recruitment occupies an important place in the dynamics of fish population. In fisheries, constituted by a few year-classes, success or failure of recruitment is immediately reflected on fisheries. In population studies a distinction has to be made between recruits which are in the fishing area but not susceptible to capture and those which are susceptible to capture.

15.4.1 Mean recruitment size

This is the mean size at which the young ones are available in the fishing area. Though vulnerable they are not captured because of small size. These fishes may be classed under 'pre-recruits'.

15.4.2 Mean selection size of recruits

This is the mean size at which fish first become available to the gear and represent the size for a particular mesh. For gears of diverse meshes operating on the same recruits there will be as many mean sizes. Under such circumstances find out the dominant gear and its mesh size.

15.4.3 Sampling for recruitment study

The abundance of recruits is governed by pre-recruits which in turn, are determined by hatchlings and the latter by successful spawning represented by fertilised egg production. For the purpose of the present investigations, data may be collected on the following :

1. quantitative estimation of spawn (hatchlings)/standard shooting net/hour
2. catch of pre-recruits (species-wise)/standard special gear/hour and
3. catch of recruits (species-wise)/standard experimental gear or commercial gear/hour

(Note : Any unit time can be taken for computational advantages).

(a) Quantitative estimation of spawn (hatchlings) per unit of effort

1. From 2.0 mm meshed netting prepare shooting nets of following description :

Net proper

Length	:	350 cm
Width of entrance mouth	:	150 cm
Height of entrance mouth	:	50 cm
Ring diameter	:	20 cm

Tail piece (gamcha)

Material : handloom square netting cloth

Length	:	125 cm
Height	:	45 cm
Width at rear end	:	35 cm

Because of the unfavourable terrain in upper stretches of river feeding the reservoirs smaller samplers (shooting nets) as given above are recommended.

2. The survey of river stretches for spawn collection takes into consideration (i) the incoming tributaries/nallas to the main stream (ii) current - exposed shores (iii) sheltered shores (iv) gradient of the bank (v) river bends (vi) nature of basin and any other topographical /terrain features. Zonate river stretch into as many strata as possible as indicated above and note down the areas under each

of the above (or more) heads. Ply shooting nets strictly randomly (not in any set pattern) covering all the above strata. In addition take samples the river (say mid - stream) by rectangular townets of $\frac{1}{3}$ the area of the mouth of the shooting net, subject to velocity of the current permitting such operations.

For further details on spawn collection, refer to the account given by Central Inland Fisheries Research Sub-Station, Allahabad (enclosed herewith).

(b) Catch of pre-recruits per unit of effort

1. Sample pre-recruits by fry dragnet of 30 x 50 m with meshes of 3 mm.
2. Express the catch (nos./wt) species-wise per unit time (say per hour) per standard length of gear.
3. Note down the number of hauls and duration of each haul. Extend the sampling such that it covers the entire distribution of fry/fingerlings.

Catch of pre-recruits, if properly carried out between intervals of time, will provide parameters of natural mortality. They will also provide clues regarding suitability or otherwise of meshes of commercial gears to counteract in cases where natural mortality of pre-recruits is very high.

(c) Catch of recruits per unit of effort.

1. Recruits are covered by commercial gears and their abundance is revealed by catch per unit of effort of commercial gears. Refer earlier section on catch per unit of effort.
2. If multiplicity of gears do not give correct abundance index of recruits sampling for population including recruits should be done by experimental gears.

(Note: By collecting statistics of catch per unit of effort for spawn for some years it is possible to predict the abundance of pre-recruits giving allowances for environment-caused, variable mortalities on spawn. Similarly, statistics of catch of pre-recruits per unit of effort collected over the years will throw light on the relative abundance of recruits which, in turn, will throw light on other age-groups constituting fishery.)

15.5 Mortality rates

15.5.1 Estimation of mortality rate on the basis of catch per unit of effort

In fisheries where recruitment shows marked variability, it is necessary to compare the catch per unit of effort of individual year classes in successive years in order to get estimates of survival rate.

1. Compute the catch per unit of effort for various year classes constituting the fishery for successive years $x_1, x_2, x_3 \dots$ etc.

2. Compute survival rate as :

$$s = \frac{v + 1 \frac{N}{x + 1}}{v \frac{N}{x}} \quad \text{where,}$$

v and x represent age group and year respectively

3. Find out independently survival rates for all year classes for all successive years for which data are available.
4. If survival rate does not glaringly vary between year classes between years a geometric mean may be computed to indicate average survival rate.

$$a = 1 - s \quad \text{where,}$$

a = mortality rate

15.5.2 Catch curve to estimate survival rate

Where the recruitment does not vary markedly a catch curve can be constructed to estimate the survival or mortality rates. Here the log frequency is plotted against size, or the log frequency against age. The latter is better if age can be precisely estimated. The curve has an ascending and a descending limb but only the latter limb has use in the computation of survival rate.

1. Find out the difference in logarithms between ages $t + 1$ and t
2. The result of the above will be negative and can be written with positive mantissa and then antilogged. This gives survival rate.

15.5.3 Fishing and natural mortality rates

Refer 15.3 for method and computation.

15.6 Growth rate of fishes

The individuals of a brood, after hatching start registering growth but their number starts dwindling due to mortality. In order to compute weight yields from recruits it is necessary to balance the individual rate of increase in weight against the rate of decrease in numbers. The growth rate in fishes can be expressed in terms of (1) absolute growth rate (2) relative growth rate and (3) instantaneous rate of growth.

1. Absolute growth rate = $\frac{W_1 - W_0}{t_1 - t_0}$ where,
 $W_0 = wt$ at any time t_0
 $W_1 = wt$ at a later time t_1
2. Relative growth rate $\frac{(W_1 - W_0)}{W_0 (t_1 - t_0)}$
 (for % growth rate multiply by 100)
3. Instantaneous growth rate = $\log e (W_1 / W_0)$
 when $t = 1$

15.7 Eumetric fishing

15.7.1 Yield - intensity curve

The yield variations corresponding to the various fishing intensity with mesh size remaining constant, when plotted, provide a curve known as yield - intensity curve. Here the yield is a function of fishing mortality coefficient.

15.7.2 Yield - mesh curve

The yield variations corresponding to mesh variations with fishing intensity remaining constant, when plotted, provide a curve known as yield - mesh curve. here the yield is shown as a function of age/size at entry to the exploited phase of the fishery.

15.7.3 Eumetric yield curve

The kind of yield - intensity curve in which the mesh is adjusted throughout in order to obtain the maximum possible yield at each level of fishing intensity is known as eumetric yield curve.

15.7.4 Eumetric fishing curve

The curve that defines the relation between fishing intensity and the age/size at entry to the exploited phase is termed as eumetric fishing curve.

16. FORMULATION OF MANAGEMENT POLICY TO INCREASE PRODUCTION

The management policy to get optimum yield of fish in reservoirs should be based on the following :

1) Rational exploitation of natural stocks taking into consideration the primary components of fish population structure, namely growth, recruitment, natural mortality and fishing mortality for which references have already been made in this handbook and 2) development of a suitable stocking policy for non-self stocking fish population taking into consideration ecological suitability. The following guidelines are given for stocking of fish in reservoirs.

1. Basic fertility of the water (refer section 5 & 6)

2. fish food resources of the reservoir (refer sections 9, 10 and 11)
3. the selection of fishes to be introduced (in the context of the fish food resources of the reservoir on the basis of item No. 2)
4. volume and area of the reservoir (refer section 2)
5. anticipated production from stocking per hectare (on the basis of existing yield (kg)/hectare and basis fertility of reservoir)
6. Size (and weight) of the fingerlings at release (taking into consideration environmental suitability and predatory fishes)
7. growth rate of fingerlings (refer section 15.6)
8. anticipated mortality for released fingerlings (to be subsequently verified from tagging experiment refer section 15.5)

The following formula may be followed in estimating the number of fish per hectare to be stocked :

$$N = \frac{S_1 - S_0}{G} + M \text{ where,}$$

N = the number of fish/unit area/unit time

S_1 = the fish biomass/unit area at the end of unit period

S_0 = the fish biomass/per unit area at the beginning of unit period

G = the average increase (wt) per fish

M = anticipated mortality (in nos.)

To explain the above formula :

For example, in a reservoir 100 kg of fish production per hectare is expected. The fingerlings at release weigh on an average 25 gm and reach a size of 425 gm at the end of the unit period (say, a year). The number of fingerlings to be stocked are estimated as under giving a 10% mortality.

$S_1 - S_0 = 100$ kg/hectare/unit period; $G = 425$ g - 25 g = 400 g/unit period; $M = 10\%$ mortality; $N =$ Number of the fingerlings to be stocked to be estimated; $N = \frac{100}{0.4} + 25 = 250 + 25 = 275/\text{ha}$.

17. ECONOMICS OF THE PROJECT

The ultimate aim of fisheries development is to produce more fish per unit area and to earn revenue for the agency concerned. Unless the project gives sufficient return on investment the development work is not worthwhile. It is necessary that data on items of expenditure and income be maintained to prepare profit and loss account projectwise and check the working financially. In the present hand book the entire project including the fish farm has been taken as one composite unit. The ice plant and cold storage have, however, been treated as distinct from the reservoir, the economics of which separately recorded. The data may be maintained as per proforma 29-30 on Expenditure and Revenue, and Ice Plant.

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APPENDIX - I

Calibration of ocular micrometer

Ocular micrometers are used to measure microscopic objects (say, planktonic organisms, eggs, larvae etc.). These micrometers are glass discs bearing a linear scale of parallel, engraved, equidistant lines. Also available are ocular micrometers with sub-divided squares designed to accurately delimit microscopic fields (Whipple ocular micrometer).

In order to calibrate an ocular micrometer a stage micrometer is used as the object of known dimension. The latter is a standardised precisely ruled scale mounted on glass slide. The ocular micrometer is fitted to the eye-piece and the stage micrometer is placed on the microscope stage. The ocular and stage micrometers are so adjusted that they (their images) are parallel and partly superimposed. A marking at one end of ocular micrometer is selected and superimposed on a similar line on the stage micrometer. A sweep of eye downward would indicate the only exactly corresponding lines of stage and ocular micrometers. Since the distance between lines on the stage micrometer is known, the linear value of each ocular division can be computed.

Example :

25 divs. of ocular micrometer = 10 divs. of stage
(o.m.) micrometer (s.m.)

(1 div. sm. = 0.01 mm)

$$1 \text{ div. of o.m.} = \frac{10 \times .01}{25} = 0.004 \text{ mm} = 4 \text{ microns}$$

(Note : Note down the microscope, the powers of eye piece and objective and the corresponding calibration of ocular micrometer. The procedure for calibration of whipple ocular micrometer is the same as above except the sides of the largest square will have to be calibrated with stage micrometer).

APPENDIX - II

Table - 1

Table for the dilution of commercial formalin

Grade of formalin required (%)	Vol. of 40% formalin (ml)	Vol. of distilled water to be added (ml)
3	7.5	92.5
5	12.5	87.5
8	20.0	80.0
10	25.0	75.0
15	37.5	62.5
20	50.0	50.0

Table - 2

Table for the dilution of 96% alcohol (Rec. spirit)

Grade required (%)	Vol. of rect. spirit (ml)	Vol. of distilled water (ml)
90	93.5	6.5
80	83.3	16.7
70	72.9	27.1
60	62.5	37.5
50	52.1	47.9
40	41.6	58.4
30	31.2	68.8

Table - 3Conversion tableLength

1 inch = 25.4 millimetres
 1 foot = 0.3048 metres
 1 mile = 1.6093 kilometres

Area

1 sq. inch = 6.4516 sq. centimetres
 1 sq. foot = 0.09290 sq. metres
 1 acre = 0.404686 hectares
 1 sq. mile = 2.5900 sq. kilometres

Volume and capacity

1 cu. inch = 16.3871 cu. centimetres
 1 cu. foot = 0.028317 cu. metres
 1 cu. foot = 28.316 litres
 1 acre foot = 1233.48 cu. metres
 1 gallon = 4.546 litres

Weight

1 seer = 0.9331 kilograms
 1 pound = 0.45359 kilograms
 1 maund = 37.324 kilograms
 1 hundred weight = 50.802 kilograms
 1 ton = 1016.05 kilograms

PROFORMAE FOR "METHODOLOGY ON RESERVOIR FISHERIES
INVESTIGATIONS IN INDIA"

- | | | |
|---------|----|---|
| Section | 1. | Topographical and morphometrical features |
| " | 2. | Physical and chemical features |
| " | 3. | Biological features |
| " | 4. | Fish and fisheries |
| " | 5. | Economics |

APPENDIX - III

Proforma-1

MORPHOMETRY

Sec. 1.1

1. Name of the Reservoir : Name of the river demmed
2. Location :
 - a) Lat./Long.,: b) State :
 - c) District : d) Nearest Town/Rly. Stn. and distance:
3. a) Year of construction :
b) Total cost of construction :
4. Purpose - Irrigation/Hydel/Flood control
5. Dam - Masonary/Earthen/Earthen-cum-masonry
 - a) Length b) Height upto spill way
 - c) Height upto crest level d) No. & size of sluice gates
 - e) No. and size of river bed sluices
6. Levels, area and volume :
 - a) Level (M.S.L.) b) Area (ha) c) Vol. (m.c.ft.)
 - i) River bed : _____
 - ii) Dead storage : _____
 - iii) Full reservoir : _____
7. Area irrigated and main crops :
8. Power generated - M.K.W.

9. Rivers and streams falling in reservoir

Name	Length	Perennial/seasonal
------	--------	--------------------

10. Catchment area with average rainfall :

11. Area submerged - Forest/Agricultural/Rocky

12. Any factory effluents discharged in reservoir/nature of effluent :

13. Year of start off fishery exploitation :

14. Exploited by - Fishery Dept./Irrigation/Electricity Board/Forest/Local body

15. Fishermen population around the reservoir

Name of village	Population
-----------------	------------

16. Ice factories near reservoir :

Production capacity/day

a) Private :

b) Government :

17. Fish Farm :

	Number	Area
Nursery		
Rearing		
Total		

Proforma-2

Sec. 1.2

Inflow - outflow record

Month and year _____

Date	Discharge into reservoir (cusecs)	Discharge out of the reser- voir (cusecs)	Water level of the reser- voir (metres)
------	---	---	---

Proforma- 3

Sec. 1.3

Reservoir level and water spread records

Year _____

Month	Max.level of reservoir (metres)	Min.level of reser- voir (metres)	Av.level (metres)	Av.area (hectare)	Av.capa- city (hect.metre)
-------	---------------------------------------	--	----------------------	----------------------	----------------------------------

Note : Average level of the reservoir should be computed from the daily reservoir level readings.

Proforma- 4

Sec. 2.1

Meteorological Records

Months	Precipitation (in inches/mm)	Average wind speed (mph/ kmph)	Air temperature		
			Maxi- mum (°C)	Mini- mum (°C)	Average (°C)

Proforma- 5

Sec. 2.2

Soil analysis records

Date

Zone of sampling

Depth	pH	Organic carbon (%)	Total nitrogen (%)	Available nitrogen mg/100 gm soil	Available phosphorus mg/100 gm soil	Free cal- cium car- bonate (%)

PLANKTON- I

Net type
 Diameter of the net mouth
 Haul type - vertical/horizontal

Date
 Weather
 Wind velocity
 Wind direction

Station	1	2	3	4	5	6	7	8	etc.
Time									
Depth at station									
Length of vertical haul									
Vol. of plankton concentrate in sample									
Vol. per cubic meter									
Zooplankton (in Nos.)									
Phytoplankton (in Nos.)									

Note : Sample measurements of individual plankters should also be taken and shown on the reverse side specieswise

PLANKTON - II

Non-net sampler type :

Date

Capacity of the sampler :

Weather

Depth at Station
(Contour)

Wind velocity

Wind direction

: 1 : 2 : 3 : 4 : 5 : 6 : 7 : 8

Depth at operation

Time

Vol. of plankton concentrate in sample

Vol. per cubic meter in the reservoir

Zooplankton (Nos.)

Phytoplankton (Nos.)

Note : Sample measurements of individual plankters should also be taken
specieswise/generawise

PLANKTON- III

Species	Disp. Vol. (ml)	Wet weight (mg)	Dry weight (mg)	Organic weight (mg)	Size	Total organisms (Nos.)	Remarks
---------	--------------------	--------------------	--------------------	------------------------	------	---------------------------	---------

Note. The above records may be confined to zooplankton only

Macro aquatic vegetation

Area of quadrat sampler

Date

Sample No.	1	2	3	4	5	6	7	8	9	etc.
------------	---	---	---	---	---	---	---	---	---	------

Location

Nature of bottom

Depth

Species : Weight

1.
2.
3.
etc.
Total

Note. If the plants are in flowering stage.

Bottom biota

Date
Type of dredge
Area of dredge

Sample	1	2	3	4	5	6	7	8	9
--------	---	---	---	---	---	---	---	---	---	-------

Location

Nature of bottom

Depth (metres)

Vegetation

Volume of sample (ml)

Weight of sample (gms)

Bottom organisms in sample (Nos.)

1.
2.
3.
etc.

Miscellaneous

Total

No. per sq. m.

Volume (ml per sq m)

Yield Records
(Landings)

Proforma- 13
Sec- 4.1

Date of sampling	Total catch (kg)	Specieswise catch											
		Wt.	Number	Wt.	Nos.	Wt.	Nos.	Wt.	Nos.	Wt.	Nos.		

Note : Compute the total catch and specieswise catch for the months on the basis of randomly sampled days' catches. Give allowance for non-fishing days.

Proforma- 14

Fishing Effort Records
(To be used for gill nets)

Sec.-4.2

Date

Area of operation

Sl.No. of parties	No. of persons in party	No. of boats in party	Hours of operation	No. of nets in party	No. of pieces in net with dimension and mesh size (bar)	Total catch sp.wise and net-wise	Total No. of fish of each species netwise	Av. size of fishes caught in net specieswise	Av. wt. of fishes in net species-wise

- Note: 1. Show dimension of each piece by length and width in metres
2. Specieswise size frequency to be written on the reverse side.

Fishing Efforts Records

(for nets other than gill nets)

Date

Type of gear

Dimensions of net

Mesh size or average mesh size
(bar measurement)

No. of fishermen engaged

Duration of each haul

Species composition	Catch per operation (Wt/Nos.)							Average catch per haul
	1	2	3	4	5	6	7	
1.								
2.								
3.								
etc.								
8. Misc. fishes								
Total								

Note : The size composition of species of each of the haul, should be attached to this Data Sheet or written on the reverse side of this sheet.

Proforma- 16

Sec. 4.4

Mesh Selectivity Records

Date _____

Name of the gear _____

Species	Total length (mm)	Wt. (gms.)	Sex	Mesh (bar) (mm)/twine thickness	Natural girth at operculum (mm)	Constricted girth at operculum	Natural girth at 1st Dorsal (mm)	Constricted girth at 1st dorsal (mm)	Natural girth mid-way between operculum & 1st dorsal (mm)	Constricted girth mid-way between operculum & 1st dorsal (mm)

Note : 1. Where shore seine with cod-end is operated the cod end may be covered with a close meshed net to collect the escaping fish.

2. Under 'sex' column indicate whether the fish is mature or immature.

Proforma - 17

Sec. 4.5

Length Frequency Records

Name of gear* _____

Year _____

Species	Class Interval (mm)	Class mark (mm)	Length Frequency											Pooled frequency %			
			J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.		D.		

Note : * The above data can be entered gear-wise where possible.

Fish Scales Records

Sec. 4.6

Species

Date of collection	Serial No.	Fish length Sex (total) mm	Sex	Scale length (total) mm	Measurement to scale rings from focus (mm)										Remarks		
					0	1	2	3	4	5	6	7	8	9		etc.	

Note : 1. Under 'remarks' column indicate the nature of the outer edge of the scales.

2. Measure scale lengths from the focus to the posterior ends both for total length and for 'ring' lengths either at $\angle 45^\circ$ or $\angle 90^\circ$

Sec. 4.7

Length-weight Relationship

Species

Date	Sex	Total length (mm)	Standard length (mm)	Furcal length (mm)	Wt. (gm.)	Remarks

Note : Under 'Remarks' column indicate gear of capture for each fish.

Separate proforma is to be used for each species.

Proforma - 20

Index of condition

Sec. 4.8

Name of the gear _____

Year _____

Name of the fish _____

Class Interval	Class mark	K values											
		J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.

Average values
of K _____

Proforma - 21

Gonad and maturity

Sec. 4.9

Date	Species	Total length (mm)	Wt. (gms.)	Sex	Wt. of gonad (gms)	Extent of the ovary/testis in the body cavity	General appearance of the ovary/testis	Range of ova diameter	Appearance of ova (under microscope)	Maturity stage	Remarks
1	2	3	4	5	6	7	8	9	10	11	12

- Note : 1. Under column 11 indicate stages of maturity like I, II, III, IV etc.
2. Under column 12 indicate physical deformities, parasitic infection etc. of gonads.

Proforma - 22

Sec. 4.10

Species						<u>Fecundity</u>		R e m a r k s
Date	Total length of fish (mm)	Weight of fish (gms)	Weight of gonads (gms)	No. of mature eggs per sampled weight	Total No. of mature eggs in ovary			

Note : Under 'Remarks' column indicate whether the gonads are parasites-infected or otherwise have any physical deformity. Indicate further whether species have more than one spawning in a season. Fecundity should include total number of mature eggs that are shed in a season.

One pforma is to be used for each species.

Proforma - 23

Sec. 4.11

<u>Gut contents</u>									
Date	Species	Total length (mm)	Weight (gm)	Sex and stage	Weight of gut and contents	Condition of stomach	Volume of food in stomach	Percentage volume of different food items	Remarks

Note : Under 'Remarks' column indicate undigested rectal contents. Parasitic infection, if any, of the gut may also be indicated under this column.

Proforma - 24

Sec. 4.12

Index of preponderance

Name of the fish _____

Month/Year* _____

Food items	% of occurrence (o_i)	% of volume (v_i)	v_i	o_i	$\frac{v_i o_i}{\sum v_i o_i} \times 100$

Note: *The data may be analysed on a yearly basis. Monthly analysis can also be done, if found necessary

Proforma - 25

Sec. 4.13

Forage RatioName of the gear
of capture.

Name of the fish _____

Month/Season/Year _____

Food items	% in stomach	% in environment	Forage ratio

Note: 1. Forage ratio is constructed only to bottom feeding fishes.

Proforma- 28

Sec. 4.14

Tagging Records- I
(Growth and Migration)

Species of fish	Date of release	Point of release	Date of recovery	Point of recovery	Total length at release (mm) A	Total length at recovery (mm) B	Growth (mm) B - A	Duration of free life in days	Mode of capture (indicate gear)	Sex, state of maturity and state of feed of recovered fish	Condition of fish
1	2	3	4	5	6	7	8	9	10	11	12

Note : Item 11 to be recorded after dissection of fish

Item 12 indicate whether recovered fish is healthy or otherwise to determine the after-effects of tagging.

Proforma- 27

Sec. 4.15

Tagging Records- II
(for estimation of population parameters)

Date	Number tagged	Size tagged	Tagged fish recovered	Untagged fish recovered	Date of recovery	Size recovered	Remarks
------	---------------	-------------	-----------------------	-------------------------	------------------	----------------	---------

Stocking Record

Area of the reservoir
 Av. water capacity of
 the reservoir

Date	Species	Size of fingerlings at release (mm)	Wt. of fingerlings at release (gm)	No. of fingerlings released	Time of release	Place of release	Place of release	Water temp. °C	Condition of fry	Source of stocking material (from river or induced bred)
1	2	3	4	5	6	7	8	9	10	11

Note: If fry/fingerlings show any sign of fin rot or other affliction their percentages should be computed and indicated under column 9.

I. EXPENDITUREA. Capital

	<u>Year</u>	<u>Budget provision</u>	<u>Expenditure</u>
1) Fish Farm			
2) Buildings			
a) Office & Lab.			
b) Residential quarters			
3) Tubewell for farm (if any)			
TOTAL			

B. Non-recurring

	<u>Year of purchase</u>	<u>Cost</u>
1) Vehicle		
2) Motor launch		
3) Motor boat		
4) Outboard engine		
5) Water pump		
6) Country boat		
7) Gear		
8) Scientific equipment		
9) Field equipment		
10) Furniture		
11) Others		

Contd.... Proforma - 29C. Recurring expenditure (Yearwise separately)

- 1) Pay, D.A., T.A. of staff
- 2) Office contingencies
 - i) Electricity and Telephone
 - ii) Printing and Stationery
 - iii) Postage and Insurance
 - iv) Advertisements
- 3) Other contingencies

Expenditure on	Running and Maintenance	Repairs	Staff	Total period for which is remained out of use due to defects
1) Vehicles				
2) Motor Launches				
3) Outboard Motor Boats				
4) Pumps				
5) Other equipments				
6) Repair & Maintenance of farm				
7) Repair & Maintenance of Buildings				
8) Repair & Maintenance of Gear				
9) Purchase of Fertilisers -				
Organic :				
Inorganic:				
10) Purchase of Fish Food				
11) Purchase of Stocking material				

Contd.... Proforma- 29

- 12) Purchase of Gear
- 13) Purchase of Chemicals & Glasswares
- 14) Purchase of Equipment
- 15) Purchase of Books
- 16) Others
- TOTAL

(I) Total expenditure during the year - 6% on A +
Depreciation on B + C =

II. REVENUE

- 1) Sale of fish
- 2) Sale of spawn and fingerlings etc.
- 3) Sale of other farm produce
- 4) Sale of condemned material
- 5) Other miscellaneous items
- TOTAL

Net Revenue = II - I

Rates of sale of fish (groupwise i.e. carps, catfishes, minnows etc.)

Rates of fishing charges (groupwise i.e. carps, catfishes, minnows etc.)

Average rate per kg of fish :

Fishing charges as % of sale price :

Production per hectare of water area :

