# Chapter - 1

# INTRODUCTION

## The Lacuna

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## Aim and Objectives

## Introduction:

A RESERVOIR may be defined as a natural or manmade pond where water accumulates and is stored for various uses, especially for supplying a community, irrigation land, hydropower generation etc. Prehistoric man used to dam streams by putting sticks or bamboos across a stream or channel. Variety of masonry constructions like dams, weirs, barrages etc. fulfill the purpose of storage of water by creating surface water sheets usable for irrigation, water supply, electricity generation etc.

Depending upon the size and shape of reservoir as well as seasonality, the temperature regime is different; however in tropical countries marked variations are not registered. The chemical characteristics of soil and water of the reservoir vary with the depth and age of the reservoir. Plankton abundance depends upon the season, nutrient status of impoundment and geographical conditions of the reservoirs. More chlorophyceae are indicative of healthy situation and moderate growth of aquatic plants is supportive of better quality fauna, particularly fishes.

In last six decades, need of fresh water for the purpose of irrigation, energy generation, civil supply etc. has been fulfilled by developmental activities like harnessing river systems and generation of reservoirs in India. To overcome the problem of potable fresh water supply at local level, several minor irrigation projects were implemented resulting in to generation of extra surface water sheet. These vital resources of reservoirs were not attended critically for inland fishery development in India. Studies conducted by Central Inland Capture Fisheries Research Institute (CICFRI) as the All India Co-ordinate Project on Reservoir Fisheries (AICPRF) took the lead in evolving methodology for evaluation of reservoirs and their fisheries status.

Following directions as the outcome of AICPRF central as well as state Governments have started generating database for reservoir fisheries status of India. Even then surprisingly the required database on the reservoir fisheries of India taking in to account the total water area under different categories of manmade reservoirs their biogenic production propensities and fish yield potential etc. is lacking.

Fish seed committee of the Government of India (1966) termed all water bodies of more than 200 ha in areas as reservoirs. David et al. (1974) classified water bodies of Karnataka state, considering impoundments size above 500 ha as reservoir and named the smaller than that as irrigation tanks. However, no uniform classification criteria were set for reservoirs. Generally the reservoirs are classified as small (< 1000 ha), medium (1000 to 5000 ha) and large (>5000 ha) as per the records of Government of India (Srivastava et al., 1985; and Sarma, 1990). As per present status of Indian reservoirs, total number of 19370 reservoirs cover approximately 3153366 ha surface area. Type-wise status of reservoirs is presented in Table – 1.1.

**Table – 1.1: Type-wise status of reservoirs.**

| | **Small Reservoir** | | **Medium Reservoir** | | **Large Reservoir** | |
|---|---|---|---|---|---|---|
| | Number | Area (ha) | Number | Area (ha) | Number | Area (ha) |
| India | 19134 | 1485557 | 180 | 527541 | 56 | 1140268 |
| Gujarat | 676 | 84124 | 28 | 57748 | 07 | 144358 |
| Rajkot | 16 | 5166 | 08 | 13798 | -- | -- |

**(Source: Modified from Sugunan, 1997).**

The reservoir ecology differs in some important characteristics from flowing water or a small pond like impoundment. The size and shape of reservoir influences its productivity depending upon catchment area and degree of siltation. Usually, transparency of water is good except the flow of suspended materials as physical load or density of planktonic matter and algae as organic load.

The fish production potential of a reservoir is determined by its key environmental parameters, especially the water and soil qualities which, in turn, are the functions of the geo-climatic conditions under which it exists. Thus, the geography, climate, topography and a number of physiographic parameters play a vital role in the productive potential of the reservoir. Due to ever increasing demand of fresh water at one end and scanty surface water resources, and erratic rainfall system, the reservoirs have become a common feature of the Indian landscape, dotting all river basins, minor drainages and seasonal streams (Sugunan, 1997). The reservoir ecosystem represents dual nature, during the monsoon months of heavy inflow and outflow, the

whole reservoirs mimics a lotic environment where as in summer, when the inflow in to and outflow from the reservoir dwindle, a more or less lentic conditions prevails in most part of it.

Thus, the ecology of reservoir is radically different from that of the parent river. The changes in the hydrology trigger off transformation of lotic environment in to lentic one. The variation in the abiotic and biotic factors affects productivity of reservoirs at different trophic levels which finally affects fishery potential of the reservoir (Table-1.2). Nutrient budget of the reservoir contributes to its biological potential as well as fisheries sustainability along with several abiotic factors.

The ranges of abiotic factor indicating their productive status are given in Table – 1.3, the range of values of such quality parameters can be used as a dependable yard stick to protect the organic productivity production propensities and can be used to determine by variety of factors.

The highly seasonal rainfall and heavy discharge of water during monsoon do not favour colonization by macrophytic communities in most of the reservoirs. A rich plankton community with well marked succession is the hallmark of the Indian reservoirs. Aquatic macrophytes do not show their presence prominently in the reservoirs due to water mass movement, topography of reservoir and possible pollution stress. Mostly patches of submerged or emergent macrophytes and mats of Spirogyra are found in the reservoir. Benthic invertebrate fauna shows an erratic distribution in Indian reservoirs. Even though substratum variation, water level fluctuation and deposition of silt which retards benthic community, a number of reservoirs harbour rich community of benthic invertebrates. In spite of lotic to lentic conditional changes and several other micro-environmental variations, Indian reservoirs sustain a rich variety of fish species. The three Indian major carps are stocked extensively in reservoirs all over the country, resulting in 82 to 90 % contribution in the total catch. The native ichthyofauna contributes to approximately 10 to 20 % of total yield.

**Table - 1.2: Abiotic and biotic factors affecting productivity of reservoirs at various trophic levels**

| Positive/augmentative factors | Major effects unknown | Negative/reductive factors |
|---|---|---|
| Low mean depth (less than 18 m) | High rate of evaporation | High mean depth |
| Existence and extent of marginal vegetation | Contributions of autochthonous nutrients | Erosion in the reservoir water shed area |
| Optimum nutrient levels | High surface temperature during summers (in northern India) | Reduction of quantity of water flowing into reservoir |
| Nutrient enrichment during floods | Low water temperature during winter (in northern India) | Large water level fluctuations creating large aridal (barren littoral) |
| Moderate to long growing season | Aquatic community interrelationship | Low level of dissolved oxygen in parts of hypolimnion |
| High frequency of phytoplankton blooms | | Pollution in the reservoir water- shed |
| Moderately developed macrophyte community | | Phytoplankton biomass mainly blue greens |
| Well established plankton and benthos | | Unbalanced fish populations favouring predatory and trash species |
| Conditions permitting passage of migratory fish | | Relatively low environmental heterogeneity |
| Introduction of fishes adapted to lentic conditions | | Low diversity of plankton and benthos |
| Employment of modern fishing gear and optimization of fishing effort | | Low diversity of aquatic macrophytes |

**(Source: Jhingran, 1988)**

**Table – 1.3: Physico-chemical features of Indian reservoirs (Range of values)**

| Parameters | Overall range | Productivity | | |
|---|---|---|---|---|
| | | *Low* | *Medium* | *High* |
| **WATER** | | | | |
| pH | 6.5–9.2 | <6.0 | 6.0–8.5 | >8.5 |
| Alkalinity (mg $l^{-1}$) | 40–240 | <40.0 | 40–90 | >90.0 |
| Nitrates (mg $l^{-1}$) | Tr.-0.93 | Negligible | Upto 0.2 | 0.2–0.5 |
| Phosphates (mg $l^{-1}$) | Tr.-0.36 | Negligible | Upto 0.1 | 0.1–0.2 |
| Specific conductivity (µmhos) | 76–474 | | Upto 200 | >200 |
| Temperature (°C) | 12.0–31.0 | 18 | 18–22 | >22 |
| | | (with minimal stratification : *i.e.*,>5°C) | | |
| **SOIL** | | | | |
| pH | 6.0–8.8 | <6.5 | 6.5–7.5 | >7.5 |
| Available P (mg/100 g) | 0.47–6.2 | <3.0 | 3.0–6.0 | >6.0 |
| Available N (mg/100 g) | 13.0–65.0 | <25.0 | 25–60 | >60.0 |
| Organic carbon (%) | 0.6–3.2 | <0.5 | 0.5–1.5 | 1.5–2.5 |

**(Source: Jhingran, 1990)**

## 1.1 The lacuna:

Principally reservoirs are created with the aim of irrigation and water supply management but availability of this type of surface water sheet can be utilized for several other purposes. Fishery element of such reservoirs generates additional economy as well as employment. The economic gain may be considered in two folds i.e. money generated from fisheries source and proteinous nutrition in the form of fishes in respect to surrounding population.

Generally all reservoirs are paid due attention with water resource management only. The management of fisheries aspect is by and large neglected and therefore, it affects the biology, ecology and economy of reservoirs. There is a necessity of observing reservoirs with multidimensional approach over unidirectional approach of water resource management. Here in this project, the water sheet Nyari – II has been evaluated with its ecology and fisheries aspects. The result outcome is expected to be applicable to various types of reservoirs for their multidimensional exploitation and gain.

## 1.2 Present Research Status:

Present status of literature reveals notable study of reservoirs for fisheries purpose also (Mustapha, 2009; Sugunan, 1997a and b). Several limnological parameters; edaphic parameters and reservoir morphology have been used in estimating potential fish yields from reservoirs (Ryder, 1965 and Mustapha, 2009). The environmental variability of reservoirs strongly influences fish population inhabiting the same (Rekhow et al., 1987; Freeman et al., 1988).

The wide fluctuation in water level, however, is a common feature in reservoirs and has some effect on their ecology i.e. nutrient exchange between pelagic and littoral zones of reservoir (Andrew and Pfiester, 1995). Ecological assessment in the form of physico–chemical nature of abiotic factors and its relationship with biotic factors are essential to establish organic status of the reservoir. These two major factors are having direct influence on each other as well as with several sub elements of individuals. A strong correlation exists among physico–chemical properties, hence, a systematic calculation and interpretation of coefficient of correlation gives us an idea

of rapid water quality monitoring (Arvinda et al., 1995). The water quality of reservoir and the productivity status are largely controlled by the quantity and quality of external nutrient loading (Saadoun et al., 2008). Similarly bottom soil plays a significant role in maintaining chemical and biochemical condition of overlying water which in turn contributes in maintaining productivity of the reservoir. Such maintained ecology and productivity are very significant element of potential yield in the form of fisheries. The role that bottom soil plays in maintaining productivity of reservoir has directed Hickling (1971) to describe soil as "Chemical laboratory of fish pond". In view of the importance of overlying water as well as bottom soil in determining the productivity of a fish pond, an intimate knowledge about the nature and properties of these two phases need to be understood thoroughly for developing a clear idea about the ecosystem and obtaining good production of fishes from it.

As it is evident that the quality of water plays a vital role in the chemical and organic status of the reservoir, therefore, it is necessary to check and maintain water quality standards through proper management strategies. The quality of water depends on its surface temperature, various gaseous as well as salt contents and other chemically linked biochemical factors (Kumar and Kapoor, 2006). Table - 1.4 enumerates various factors and their standard ranges to consider the quality of water as appropriate and good for aquaculture practices. Such standards of physico–chemical nature of water are a necessity for better fish yield.

Moreover, soil of surrounding area of the reservoir plays important role in growth of floral component within and in the surrounding of the reservoir. The Table – 1.5 indicates category of soil quality with reference to its nutrients. These nutrients are the main components for organic nature of soil. Soil that forms the bottom of the reservoir varies greatly in chemical and physical properties. There is increasing evidence that the condition of the bottom and the exchange of substances between soil and water strongly influence water quality (Boyd, 1995).

**Table – 1.4: Water quality standards for aquaculture ponds.**

| Parameters | Fresh water |
|---|---|
| Turbidity NTU | < 30 |
| Solids (ppm) | <500 Total, 30-200(SS) |
| Temperature $^0$C | 25 - 32 |
| pH | 7.5 – 8.5 |
| Hardness (ppm) | 30 - 180 |
| Alkalinity (ppm) | 50 - 300 |
| Chloride (ppm) | 31 - 50 |
| Dissolved Oxygen (ppm) | 5 - 10 |
| Free $CO_2$ | <3 |
| Nitrate Nitrogen ($NO_3$- N) | 0.1 – 3.0 |
| Total Nitrogen (mg/l) | 0.05 – 4.5 |
| Total Phosphorus (mg/l) | 0.05 – 0.4 |
| Sulphate | 20 - 200 |
| BOD | <10 |
| COD | <50 |
| Chlorophyll – *a* (µg/l) | 20 - 275 |

**Table – 1.5: Category of soil quality**

| Parameters | Rating | | |
|---|---|---|---|
| | Low | Medium | High |
| pH | < 6.5 (Acidic) | 6.5 to 7.6 (Neutral) | > 7.6 (Alkaline) |
| Electric Conductivity | < 1.0 Normal | 1.0 to 2.0 Non desirable | > 2.0 Harmful |
| Total Nitrogen (Kg/ha) | <1200 | 1200 to 2400 | > 2400 |
| Available Nitrogen (Kg/ha) | <250 | 250 to 500 | > 500 |
| Organic Carbon (%) | < 0.50 | 0.50 to 0.75 | > 0.75 |
| Organic Matter (%) | < 0.86 | 0.86 to 1.29 | > 1.29 |
| Available phosphorus (Kg $P_2O_5$ / ha) | < 28 | 28 to 56 | > 56 |
| Zinc | < 0.5 | 0.5 to 1.0 | > 1.0 |
| Iron | < 5 | 5 to 10 | > 10 |
| Copper | < 0.2 | 0.2 to 0.4 | > 0.4 |

In tropical and sub tropical areas with highly leached soils, reservoir bottoms are often high in clay content and low in pH. Erosion of the watershed results in suspended particles of mineral soil and organic matter entering in a reservoir in run off. The desired physical nature of aquaculture pond or reservoirs is presented in the Table - 1.6. The chemical nature of soil plays important role in betterment of productivity, plankton density and floral components. The soil strongly adsorbs phosphorous, and the capacity of reservoir soil to absorb phosphorous increases as a function of increasing clay content (Boyd and Munsiri, 1996). Interaction with biotic component of reservoir the concentration of soil organic matter varies. Organic soils with 15–20% of organic carbon (30–40% organic matter) are known to be the desirable level for aquaculture. Soils with essential organic matters are known as mineral soils, such soil provides desirable state of soil quality for aquaculture (Boyd et al., 2002).

Hydro–edaphic characteristics of reservoir, represent trophic tendencies of the reservoirs. Generally in tropical conditions oligotrophic tendencies have been observed which may be due to poor nutrient status and other chemical deficiencies (Sugunan, 1997a). Nutrient budget of Indian reservoirs is characterized by low levels of phosphates and nitrates in the water as well as leachable from the soil. Reservoir morphometry is a function of height of the dam and the topography of the impounded area apart from the nature of the basin and terrain characterized; it is the design of the dam and water utility pattern that decides the influence of morphometric features on the aquatic productivity. One of the most important morphometric considerations is the mean depth that is believed to determine the productivity of the reservoirs (Rawson, 1952 and Hayes, 1957).

The shallower reservoirs have greater part of their water in the euphotic zone, facilitating greater mixing and circulation of heat and nutrients and hence higher productivity (Hujare and Mule, 2007). Generally larger reservoirs are nutrient sink therefore less productive. Even though nutrient budget variability is in direct correlation with morphometry of reservoir and productivity has less influence on fish yield.

In the tropical country like India, highly seasonal rainfall and heavy discharge of water during monsoons results in high flushing rate in the most of the reservoirs. Therefore, the consistency and productiveness of biotic component is variable. Plankton by virtue of drifting habit and short turnover period constitutes major link in the trophic structure and events in the reservoir ecosystem (Davis, 1955 and Pillai, 1986). A rich plankton community is the hallmark of Indian reservoirs that can be attributed to abiotic factors and nutrient load variability (Sugunan, 1997b). Sreenivasan (1967) found that nitrates and phosphates are lacking in south Indian reservoirs this has relation with high numerical abundance of plankton in this reservoir. Similarly Ehrlich (1957) observed that the tropical water combine low nutrient level with high production and rapid turnover. Even though aquatic macrophytes do not figure prominently in the community structure and trophic events of the reservoir, in India they play significant role in offering adequate substratum for various insects, molluscs and other invertebrate fauna.

**Table – 1.6: International standards for physical nature of soil.**

| Particle Fraction Name | USDA (mm) | ISSS (mm) |
|---|---|---|
| Gravel | >2 | >2 |
| Very Coarse Sand | 1 – 2 | |
| Coarse Sand | 0.5 – 1.0 | 0.2 – 2.0 |
| Medium Sand | 0.25 – 0.50 | |
| Fine Sand | 0.10 – 0.25 | 0.02 – 0.20 |
| Very Fine Sand | 0.05 – 0.10 | |
| Silt | 0.002 – 0.05 | 0.002 – 0.020 |
| Clay | <0.002 | <0.002 |

**(Source: Boyd et al., 2002)**

Ichthyofauna is unique as well as centered component of reservoirs that are exercised for economic gain. Fish faunal diversity of a reservoir at a given time is the result of the impact of a series of manmade and natural changes in the native fauna of the parent river. The original fauna changes and few fish species take advantage in newly generated niches in many reservoirs, transportation of fishes from other basins and

introduction of exotic species have led to radical changes in the species set up (Sugunan, 1997a).

Reservoir ecosystem with its dynamic equilibrium between abiotic factors, such as water and soil quality, and biotic factors like productivity and biodiversity sustain good fishery potential. The fisheries in the reservoir may have two different dimensions i.e. capture fisheries and culture fisheries. The native ichthyofauna contributes capture fisheries. Regular fishing operations took place with traditional crafts and gears by fishermen and the catch is either marketed fresh or preserved near the reservoir. The preservation method is usually employed as sun drying. The fish catch yield per year fluctuates that may be attributed to reservoir ecology. Many small and medium reservoirs have been selected for stocking of Indian major carps to exploit for culture fisheries (Jhingran, 1983). Jhingran and Sharma (1978) projected approximate estimate of the average fish production from Indian reservoirs being 6–7 kg/ha. However, Marshall and Maes (1994) estimated the yield from tropical shallow and well managed reservoirs averaged to 33 – 150 kg/ha/year. The estimate of possible fish yield is calculated by most widely accepted method of Ryder (1965) using morpho–edaphic index (MEI). According to Jackson and Marmula (2001) tropical and subtropical reservoirs are known to be more productive than large reservoirs due to their high primary production. Mustapha (2009) reported that the studies on the limnological aspects and their relation with fisheries potential are scanty.

## 1.3 Status in Gujarat:

Gujarat state is the 7$^{th}$ largest state of India and comprises three distinct geographic regions. Larger area of this state is semi – arid and water scarcity prone zone (BSE-GOG, 1982; GEC, 2000). Few big and several small rivers form their basin in this state. This network of small rivers and undulating terrain creates ideal conditions for water resource development projects and thus, five districts of Saurashtra region among themselves share nearly half of the reservoirs in the state. Even though, few major and several small reservoirs are located in Gujarat, the status of reservoir fisheries is very poor.

Several reasons are quoted for the low lack profile inland fisheries status in Gujarat, but major significant one is condition of scientific investigations for reservoirs of

Gujarat. Little scientific investigations have been conducted on the reservoirs of Gujarat, the small and median reservoirs were nearly neglected for their quality assessment due to size and water retention time.

Exploration of reservoirs for economical gain – fisheries – requires to be estimated for standing fish stock and its potential efficiency to increase the reward by fishing. Good fisheries sustenance is possible only if the water and soil quality is maintained. The ideal approach in such cases is to select a sample reservoir and thoroughly analyze it for ecological conditions. Inland reservoir in this case will be treated as a unit of ecosystem and the quality estimation will be done for physico–chemical properties of water and soil, the biological condition and finally fisheries aspects.

Nyari – II is one of such reservoirs of Saurashtra region that has received attention not only for irrigation purpose but also for stocking of Indian Major Carps. Regular fisheries activities have been established in Nyari – II and the fish catch is either transported to northern part of India after primary preservation on the site itself or marketed fresh at Rajkot city.

The present investigation is aimed to fulfill the necessity of narrowing the knowledge gap between in terms of quality status and fisheries of the reservoirs. The study envisage the fruitful outcome in the form of baseline data on the quality status of reservoir Nyari – II and its possible utilization for the assessment of fish yield potential as well as development of this and such reservoirs for fruitful reservoir fisheries outputs.

## 1.4 Aim:

On reviewing recent literature and analyzing present condition of the reservoir ecosystem and their exploitation for fisheries, this project was initiated. To exploit reservoirs with their best capacities it is essential to have knowledge of their structural characteristics, hydrology, environmental status, trophic status and food chain, fishery potential etc. The present study comprises major element of reservoir ecology and fisheries.

The main aim of this research work is to establish scientific link between reservoir ecology and estimation of fishery potential of the same. The work was planned to address the major components *viz.*

1. Ecological assessment of reservoir, and
2. Assessment of fisheries status of the reservoir

The reservoir itself maintains the hydro-biological status of its own by utilizing internal resources. Physical parameters for water quality such as turbidity, light penetration and water mass influence the chemical nature of the water. The parameters like dissolved gases and salts have their influence on biotic factor. Biotic factors like presence of organisms and productivity is regulated by physico-chemical status of water and base (bottom) soil. The soil plays a vital role as sink and source of inorganic and organic salts also. Soil is a vital substratum for production of hydrophytes. As the source for food to fish, the primary productivity is essential for estimation of the fish production potential of a water body (Hujare and Mule, 2007). Primary organic production is transformed as energy and recycled in the system itself. It influenced by abiotic factors in general and especially the light penetration and turbidity. Fish fauna and other fishable organisms sustain their life and attain growth using produced organic carbon. Therefore, a good ecologically balanced reservoir can result into a good site for fisheries or otherwise a potential area for fish culture activities.

For assessment of fisheries potential a scientific approach is employed. To develop fisheries component in the reservoir following components are required to be addressed, (1) Water budget and water quality status, (2) Soil quality status, and (3) Organic status of the reservoir. Apart from water supply management, if the ecological assessment of the reservoir is made a regular practice then such reservoir will prove economically worth. On analyzing fishery potential of inhabiting fishes and employed capture fishery, local market supply and basic preservation methods can be executed. Well balanced and ecologically managed reservoirs can also be used for stocking of Indian Major Carps and Exotic Carps. All these efforts in the direction of fisheries activity will certainly benefit the management systems.