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Reservoir Fisheries

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Introduction

- ❏ Harnessing the rivers for irrigation and hydro-electric power generation has been the main focus of developmental activities in India ever since the country gained independence.
- ❏ Consequently, a number of small, medium and large river valley projects have come into existence during the last four and a half decades with the primary objectives of storing the river water for irrigation, power generation and a host of other activities.
- ❏ One of the direct results of these projects is the creation of a chain of man-made lakes, dotting the Indian landscape from Kashmir to Kanyakumari and Bengal to Gujarat.
- ❏ That the man-made lakes hold tremendous potential for inland fisheries development in India has long been recognised.
- ❏ However, this vital resource is not contributing to the inland fish production of the country to the extent it should.
- ❏ Unlike the rivers, which are under the increasing threat of environmental degradation, the reservoirs offer ample scope for fish yield optimisation through adoption of suitable management norms.

- Any attempt to increase productivity in inland fisheries has to rely heavily on the reservoirs. Again, the sheer magnitude of the resource makes it possible to secure a substantial increase in production by effecting even a moderate improvement in the yield rate.
- In the developed world, fisheries of inland lakes largely cater to the recreational needs, whereas in a highly populous developing country like India, these resources can play a vital role in augmenting food production for human consumption and mitigating the protein deficiency.
- Nearly 70% of the 0.71 million fishermen in India fish in rivers, reservoirs, lakes and other inland waters.
- On account of underemployment, these inland fishermen live in abject poverty and constitute one of the most vulnerable sections of the rural society.
- Compared to the capital-intensive aquaculture enterprises, where a good part of the profit goes to the investors, development of open water fisheries is highly labour-intensive, having the potential to provide gainful employment to the weaker sections.

- The biological potential of the various reservoirs was not evaluated to any reliable extent until the 1970s, when fish yield from them stood at low level of 5 to 8 kg/ha/y.
- The investigations conducted till then were isolated attempts to unravel the ecology of individual reservoirs in one or two States.
- Organised research on reservoir fisheries was initiated in India only in the year 1971 with the launching of an All India Coordinated Project on Reservoir Fisheries (AICPRF).
- Five large reservoirs, representing distinct geoclimatic regions of the country were under its fold.
- The Project attempted to delve into all determinants of reservoir productivity, including climatic, morphometric and edaphic variables and the dynamics of biotic communities of the reservoir ecosystem in India.
- Consequently, limnology has come to be used as a mold to cast location-specific management strategy for reservoirs.
- The limnology-mediated management norms evolved by the AICPRF have come to be known as the ecosystem-oriented management (Natarajan, 1979).

- Application of these norms have resulted in a remarkable increase in fish yield in some of the Indian reservoirs.
- A three-pronged strategy comprising selection of appropriate mesh size of the fishing gear, increased effort and stocking support has paid rich dividends in Bhavanisagar and Gobindsagar, where the annual fish yields increased from 25.56 to 80.5 kg/ha and 25.0 to 76.5 kg/ha during the period from early 1970s to mid-1980s.
- The average fish yield in the country also registered an increase up to 15 kg/ha by the mid 1980s. The present yield is estimated at 20 kg/ha.

- As a sequel to increased productivity, a study on levels of employment and income in respect of 7 reservoirs was also taken up by CIFRI in 1984, so as to corroborate the findings in terms of increased income of fishermen.
- Further, it was opined that fishing operations in reservoirs should be remunerative enough to sustain fishermen who toiled on waters.
- Even apprehensions were voiced that stagnant levels of productivity might lead to occupational shift in favour of other unskilled vocations.
- Therefore, it becomes imperative to have a contingent plan to enhance productivity at least in those reservoirs whose productive potential has been well-researched.

- An objective assessment of the fish production potential of Indian reservoirs has to take into account the diverse geo-climatic regions of the country, in which the water bodies are situated.
- Productivity of reservoirs depends, to a large extent, on the synergetic effects of a number of geochemical, meteorological, morphometric and hydrographic variables and the biotic communities present in the ecosystem.
- The biomass and species number of various communities show wide variations within the country, depending on the micro- and macro environment.
- Although Indian rivers are known for their rich fish genetic resources, the composition of fish stock in man-made lakes is subject to a series of faunistic changes brought about during the impoundment.
- The fish fauna is further altered through stocking and introduction of exotic species.
- Thus, a database on abiotic and biotic parameters, and the fish stock of the reservoir ecosystem is an essential prerequisite for a meaningful management of the resource.

CLASSIFICATION OF RESERVOIRS

- Reservoirs are classified generally as small (<1 000 ha), medium (1 000 to 5 000 ha) and large (> 5 000 ha), especially in the records of the Government of India (Sarma, 1990, Srivastava *et al.*, 1985).
- All man-made impoundments created by obstructing the surface flow, by erecting a dam of any description, on a river, stream or any water course, have been reckoned as reservoirs.
- However, water bodies less than 10 ha in area, being too small to be considered as lakes, are excluded.

- After removing the anomalies in nomenclature, especially with regard to the small reservoirs, by bringing the large (above 10 ha) irrigation tanks under the fold of reservoirs, India has 19 134 small reservoirs with a total water surface area of 1 485 557 ha (Table 1).
- Similarly, 180 medium and 56 large reservoirs of the country have an area of 527 541 and 1 140 268 ha respectively.
- Thus, the country has 19 370 reservoirs covering 3 153 366 ha (Table 1).

Distribution of different Reservoirs of India

	Small	Medium	Large	Total
Number	19,134	180	56	19,370
Area (ha)	1,485,557	527,541	1,140,268	3,153,366

Source: Sugunan 1995. Reservoir Fisheries of India. FAO Fish. Tech. Paper No. 345, FAO, Rome.

Fish Production from Reservoirs

- The fish yield from reservoir is poor, varying from 0.05 kg/ha in Bihar to 35.5 kg/ha in Himachal Pradesh with national average of 20 kg/ha.
- The average national yield from small reservoirs in India is nearly 50 kg/ha, which is also low (3.9 kg/ha in Bihar to 188 kg/ha in Andhra Pradesh).
- Against this scenario, fish production from other country is very high such as China (743 kg/ha), Sri Lanka (300 kg/ha), Indonesia (177 kg/ha), Cuba (100 kg/ha), USSR (88 kg/ha) and Thailand (64.5 kg/ha).
- Thus, in spite of the availability of vast resources of reservoirs in India with conducive ecosystems, their low fish yield is attributed to their bad, unscientific management.
- The Chinese treat reservoir fisheries as culture fisheries and it is the only country in the world where culture fisheries exceed capture fisheries, and they consider hydrobiology as the key to fishery management.

Fish Yield from Reservoirs of India

States	Small	Medium	Large	Pooled
Tamil Nadu	48.50	13.74	12.66	22.63
Uttar Pradesh	14.60	7.17	1.07	4.68
Andhra Pradesh	188.00	22.00	16.80	36.48
Maharashtra	21.09	11.83	9.28	10.21
Rajasthan	46.43	24.47	5.30	24.89
Kerala	53.50	4.80	—	23.37
Bihar	3.91	1.90	0.11	0.05
Madhya Pradesh	47.26	12.02	14.53	13.68
Himachal Pradesh	—	—	35.55	35.55
Orissa	25.85	12.76	7.62	9.72
Average	49.50	12.30	11.43	20.13

Source: Sugunan V V. 1995. Reservoir fisheries in India, *Fisheries Technical Paper*. No. 345, Rome, FAO: 423 p.

Present yield and potential of production from different categories of reservoir of India

Category	Total available area (ha)	Present		Potential	
		Average production (kg/ha)	Fish production (tonnes)	Average production (kg/ha)	Fish production (tonnes)
Small	1,485,557	49.90	74,129	100.00	148,556
Medium	525,541	12.30	6,488	75.00	39,565
Large	1,140,268	11.43	13,033	50.00	57,013
Total	3,153,366	29.70	93,650	77.70	245,134

Source: CIFRI (ICAR), Barrackpore.

Table 11.2 State-wise area (ha) of small, medium and large reservoirs of India

States	Small	Medium	Large	Total
Tamil Nadu	315,941	19,577	23,222	358,740
Karnataka	228,657	29,078	179,556	437,291
Madhya Pradesh	172,575	149,259	138,550	460,384
Andhra Pradesh	201,927	66,429	190,151	458,507
Maharashtra	119,515	39,181	115,054	273,750
Gujarat	84,124	57,748	144,358	286,230
Bihar	12,461	12,523	71,711	96,695
Orissa	66,047	12,748	119,403	198,198
Kerala	7,975	15,500	6,180	29,635
Uttar Pradesh	218,651	44,993	71,196	3,34,840
Rajasthan	54,231	49,827	49,386	153,444
Himachal Pradesh	200	—	41,364	41,564
Haryana	282	—	—	282
West Bengal	732	4,600	10,400	15,732
North-eastern states	2,239	5,835	—	8,074
Total	1,485,557	507,298	1,160,511	3,153,366

Source: Sugunan V V. 1995. Reservoir fisheries in India, *Fisheries Technical Paper*. No. 345, Rome, FAO: 423 pp.

Table 11.3 Break-up of reservoirs by number and area

Place	Small		Medium		Large	
	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)
Tamil Nadu	8,895	315,941				
Karnataka	4,651	228,657				
Andhra Pradesh	2,898	201,927				
Madhya Pradesh			21	149,259		
Andhra Pradesh			32	66,429		
Gujarat			28	57,748		
Rajasthan			30	49,827		
Karnataka					12	179,566
Andhra Pradesh					7	190,151
Gujarat					7	144,358
India	19,134	1,485,557	180	507,298	56	1,160,511

Source: Sugunan V V. 1995. Reservoir fisheries in India. *Fisheries Technical Paper*, No. 345, Rome, FAO: 423 pp.

Distribution of small reservoirs and irrigation tanks in India

States	Small reservoirs		Irrigation tanks		Total	
	Number	Area(ha)	Number	Area(ha)	Number	Area(ha)
Tamil Nadu	58	15 663	8 837	300 278	8 895	315 941
Karnataka	46	15 253	4 605	213 404	4 651	228 657
Andhra Pradesh	98	24 178	2 800	177 749	2 898	201 927
Gujarat	115	40 099	561	44 025	676	84 124
Uttar Pradesh	40	20 845	-	197 806	40	218 651
Madhya Pradesh	6	172 575	-	-	6	172 575
Maharashtra	-	-	-	-	-	119 515
Bihar	112	12461	-	-	112	12 461
Orissa	1 433	66 047	-	-	1 433	66 047
Kerala	21	7 975	-	-	21	7 975
Rajasthan	389	54 231	-	-	389	54 231
Himachal Pradesh	1	200	-	-	1	200
West Bengal	4	732	-	-	4	732
Haryana	4	282	-	-	4	282
North East	4	1 639	-	600	4	2 239
Total	2 331	551 695	16 803	933 862	19 134	1 485 557

Distribution of small, medium and large reservoirs in India

States	Small		Medium		Large		Total	
	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)
Tamil Nadu	8895 [*]	315 941 [*]	9	19 577	2	23 222	8906	358 740
Karnataka	4 651 [*]	228 657 [*]	16	29 078	12	179 556	4 679	437 291
Madhya Pradesh	6	172 575	21	169 502	5	118 307	32	460 384
Andhra Pradesh	2 898 [*]	201 927 [*]	32	66 429	7	190 151	2 937	458 507
Maharashtra	-	119 515	-	39 181	-	115 054	-	273 750
Gujarat	676 [*]	84 124 [*]	28	57 748	7	144 358	711	286 230
Bihar	112	12 461	5	12 523	8	71 711	125	96 695
Orissa	1 433	66 047	6	12 748	3	119 403	1 442	198 198
Kerala	21	7 975	8	15 500	1	6 160	30	29 635
Uttar Pradesh	40 ^{**}	218 651	22	44 993	4	71 196	66	334 840
Rajasthan	389	54 231	30	49 827	4	49 386	423	153 444
Himachal Pradesh	1	200	-	-	2	41 364	3	41 564
Northeast	4 ^{**}	2 239	2	5 835	-	-	6	8 074
Haryana	4	282	-	-	-	-	4	282
West Bengal	4	732	1	4 600	1	10 400	6	15 732
Total	19, 134	1 485 557	180	527 541	56	1 140 268	19,370	3,153,366

Fish Potentiality from Reservoirs

- The average annual fish yield has been estimated at 75 kg/ha, and the projected production potential was from 80 – 200 kg/ha.
- By adopting available package of practices, developing necessary infrastructure and providing conducive socio-economic environment, it is possible to achieve production at least 1.6 lakh tonnes from reservoirs (presently it is 0.93 lakh tonnes).
- Reservoirs should receive adequate attention in future plans for inland fishery development.
- The resources hold the key for increasing inland fish production by prioritizing culture-based fisheries of reservoirs as the major means to increase fish production of India.

- Based on the average fish yield of 422 reservoirs, as 49.50 kg/ha for small, 12.30 kg/ha for medium and 11.43 kg/ha for large reservoirs and applying national fish production rate of 20.13 kg/ha to 1,485,557 ha of small, 507,298 ha of medium and 1,16,511 ha of large reservoirs, the current production rate is estimated at 74,129, 6,488 and 13,033 tonnes for small, medium and large reservoirs.
- But, with moderate increased yield rate of 100,75 and 50 kg/ha for small, medium and large reservoirs, respectively, the production is expected to be 148,556, 39,565 and 57,013 tonnes for small, medium and large reservoirs.
- Cumulatively this would boost up the present production of all reservoirs from 0.93 lakh tonnes to 2.45 lakh tonnes.

Scientific Appraisal of fish Productivity of Indian Reservoirs

- ❖ Erection of dam across the river for creating reservoir, which is now considered to be the boon to fish production, was altogether opposed long back by fishery biologist like Sir Francis Day and Dr. S.L. Hora.
- ❖ Dr. Sundera Raj was the first to evaluate effects of Mettur Dam on fisheries.
- ❖ After that, many reservoir were formed but assessment could not be made to understand as to how best altered environment could be utilized for fish production.
- ❖ A routine procedure was adopted to introduced fish seed of major carps in reservoirs with the hope that the seed would thrive, establish and contribute to rich fishery.
- ❖ Fishery development authorities had taken it granted that introduction of fish seed is the be-all and end-all of fishery management because they had no knowledge of fish behaviour in changed ecology.
- ❖ However, with lapse of time, generation of information and advancement in technology of reservoir management, things now have changed to a great extent.

- The work of reservoir fisheries development in India was done much earlier in erstwhile Madras state in 1934 by State fisheries after the formation of Mettur Reservoir across river Cauvery.
- In fact, Tamilnadu is the front-runner of reservoir fisheries research in India and elaborate studies on Mettur, Bhavanisagar, Amaravathy and Sathanur reservoirs are the most significant.
- The reservoir fishery investigations were initiated by CIFRI, Barrackpore in 1963 taking up Tungabhadra reservoir (Karnataka) for the study.
- Later gap between research and management was bridged up with launching of AICRP on “Ecology and Fisheries of freshwater reservoirs” under the control of CIFRI.
- The project attempted to have in-depth study of all determinants of reservoir productivity.
- This study of reservoirs was eco-oriented, under which 5 reservoirs like Rihand (Uttar Pradesh), Bhavanisagar (TN), Nagarjunasagar (AP), Getalsud (Bihar) and Gobindasagar (HP) were investigated.

- ✓ Application of norms of this investigation resulted in remarkable increase in fish yields of reservoirs of all categories.
- ✓ Subsequently, some more reservoirs of other states were also included in the investigation, giving recommendations to manage them scientifically.

Increase in fish yield of medium and large reservoirs by scientific management

Reservoirs	State	Yield (kg/ha/year)	
		Before	After
Yeldari	Maharashtra	3	37
Girna	Maharashtra	15	45
Ravishankarsagar	Chhattisgarh	0.22	1.5
Gandhisagar	Madhya Pradesh	1	44
Tawa	Madhya Pradesh	1.4	28
Ukai	Gujarat	30	110
Gobindsagar	Himachal Pradesh	20	100
Pong	Himachal Pradesh	8	64
Bhawanisagar	Tamil Nadu	30	94
Sathanur	Tamil Nadu	26	108

Increase in fish yields of small reservoirs by scientific management

Reservoirs	State	Yield (kg/ha/year)	
		Before	After
Chuliyar	Kerala	35	275
Meenkara	Kerala	10	105
Markonahally	Karnataka	5	70
Gulariya	Uttar Pradesh	3	170
Bachhra	Uttar Pradesh	NA	150
Baghla	Uttar Pradesh	NA	110
Thirumoorthy	Tamil Nadu	70	200
Aliyar	Tamil Nadu	27	215

Trophic Changes

- The reservoir after formation passes through 3 distinct phases – initial high fertility, trophic depression and final fertility.
- The newly formed reservoir inundates vast areas of forest and agricultural lands and consequently decay of submerged vegetation releasing nutrients causes initial fertility leading to intense development of fish food organisms – plankton, bottom microflora and fauna.
- This stage lasts for 2-3 years and is followed by trophic depression stage, caused by rapid utilization of nutrients by flora and subdued release of nutrients from reservoir-bed due to sedimentation.
- This phase is marked by low production of fish-food organisms and lower fish growth hence lesser production.

- In Indian reservoirs, trophic depression is expected of shorter duration and varies from reservoir to reservoir.
- After depression period, the reservoir recovers with accumulation of nutrients.
- The final fertility of reservoir on stabilization is somewhere near half the magnitude of initial phase, which gets adjusted to the basic productivity of basin depending on the watershed runoff and inflow.
- But in Indian reservoirs it has been shown that final fertility would be of much higher magnitude than initial, and reservoir productivity improves after ageing.

DETERMINANTS OF RESERVOIR PRODUCTIVITY

- The reservoir represent fluviatile as well as lentic characters. Sector where river joins reservoir water, it is in flowing condition, and the dam zone has stagnant lentic water.
- The sudden water-level fluctuations with inflow and outflow of water for irrigation and power generation cause changes in standing crop of reservoirs affecting production process.
- Reservoirs are spread over various types of terrains, and soil types exposed to diverse climatic conditions and they receive drainage from a variety of catchments areas with different design and purpose of dams.
- All these diversities make reservoirs different in their morphoedaphic characters.
- Therefore, the habitat variables determining productivity of reservoirs are classified into morphometric, climatic and edaphic.

Morphometric factors

- Among these factors, **depth** is the most important to be correlated with productivity because shallow reservoirs have larger proportion of substrate in euphotic zone as compared to deeper reservoirs where most of the substrate is locked up in aphotic zone.
- **Shore development** is another useful index in determining productivity denoting degree of irregularity in shoreline.
- **Fluctuations in water level**: A stable reservoir level is more conducive to growth of organisms. Sudden fluctuations in water level is harmful because plankton pulse coincide with period of least level fluctuations, and all biotic communities are in their lowest ebb during maximum level fluctuations.

Climatic factors

- The most important climatic factor is **latitudinal location** of reservoir, which determines quantum of solar energy available for photosynthetic activities.
- The latitude also determines the air temperature that plays important role in thermal and nutrient regimes of reservoirs.
- The land area of India covers 3 287 728 km², half of which lying above the Tropic of Cancer and the rest in the tropics. The southern limit is as close to equator as 8°4' N.
- In South India, specially in Kerala and western and coastal Karnataka, range in fluctuations in air and water temperatures during the year is narrow, which prevents thermal stratification in reservoirs.
- Thermal stratification is limnologically important because in thermally stratified lakes, water above (epilimnion) and below thermocline (hypolimnion) does not mix up and thereby rich nutrients gets locked up at the bottom.
- Hence, early breaking of thermocline anyhow is required for good production from lake because its longer duration is an unproductive character.

- **Wind** is another important meteorological factor that helps mixing of water, facilitating nutrient transport.
- The **rainfall** at catchment area is also very important than rainfall at reservoir site.
- The alignments of hills and their elevation have profound influence on the prevailing winds and thereby the distribution of rainfall in the country.
- India receives, on an average, 105 cm of rainfall every year, which is one of the highest in the world for a country of comparable size.
- Total amount of rainfall received annually is estimated at 400 million hectare meters (mhm), out of which 230 mhm goes back to the atmosphere as evapotranspiration, leaving 170 mhm to impregnate the rivers through surface flow (110 mhm) and regeneration (60 mhm).
- The temporal and spatial distribution of rainfall exhibits wide variations within the country.

- ❖ The main soil types are alluvial, deep and medium black, red and yellow, laterite, saline and desert, and forest and hill.
- ❖ The landscapes include some great mountains, extensive alluvial plains, riverine wetlands, plateau lands, deserts, coastal plains and deltas.
- ❖ Soil status of the catchment area affects the nutrient status of the reservoir.
- ❖ Thus, in many reservoirs, in spite of poor soil quality of the basin, the productivity is high by virtue of allochthonous nutrients.

Edaphic factors

- The **physio-chemical characteristics of water and soil** are major determinants of biogenic productivity of reservoir.
- **Water transparency** is one such physical variable significant to production. The poor light penetration may be due to planktonic bloom is a positive index of production.
- **Dissolved oxygen** - main source of dissolved O_2 in water is absorption from air and through photosynthesis.
- The dissolved oxygen of the reservoir is removed through respiration of its fauna and putrefication of organic matter.
- Thus the available dissolved oxygen in water depends on the balance of the above two processes. dissolved O_2 below 5 ppm can be lethal to biota.
- **pH** slightly above alkaline and not above 8.5 is considered conducive to productivity. A **total alkalinity** over 50 ppm and hardness above 70 ppm are indicator of better productivity.
- The electrical conductance reflects total dissolved solids, and it gives a reliable indication of edaphic quality of water.

Chemical Stratification

- Apart from physico-chemical characters of water and soil, the vertical distribution of some constituents of water acts as a reliable index of productivity of reservoirs.
- A strong decline in oxygen (oxycline) and pH coupled with an increase in bicarbonates and carbon-dioxide towards bottom of water indicates high rate of production process in a reservoir.
- The productivity of a lake is estimated from the nature of oxygen curve.
-
- When the carbondioxide in epilimnion decreases, an increase in oxygen. On the contrary to this process, when carbondioxide in hypolimnion increases, there is decrease in oxygen level (Klinograde curve).
- The klinograde curve of oxygen is considered to be productive character against orthograde when oxygen value is more or less uniform from surface to bottom.

Energy flow

- The biotic communities (producer, consumers and decomposers) in an ecosystem are linked with one another with energy chain.
- Energy flow and nutrient cycles are two important principles of ecology.
- It is important to know energetics of efficiency with which solar energy is converted to chemical energy by producers (photosynthetic efficiency), and efficiency with which this energy is utilized by consumers (ecological efficiency).

- The studies conducted in Bhavanisagar, Nagarjunasagar, Rihand and Govindasagar reservoirs have showed that photosynthetic efficiency was high in productive reservoirs like Bhavanisagar (0.412%), Nagarjunasagar (0.290%) and Gobindasagar (0.682%) but low in Rihand (0.202%).
- It is interesting to note that energy harvest as fish was much low in Nagarjunasagar (0.055%) as compared to Bhavanisagar (0.290%), which showed that management failed in harvesting fish form Nagarjunasagar though it was productive.

Ecosystem approach to management – a mean for augmenting the fish productivity

- Productivity of a reservoir is dependent on biogenic capacity to transform solar energy into chemical energy.
- The energy fixed at primary producer level passes through trophic chain and fraction of it ends up as fish flesh.
- Therefore, the structure of different food biotic communities (trophic dynamics) assumes great significance to reservoir fishery management.
- Shortening food-chain will lead to higher rates of fish production but in reservoir management there is little scope for changing community structure of plankton to increase primary productivity.
- However, alterations in species spectrum of fish may be done, and for this only stocking of fish is a successful tool in management.

Assessment of Fish Production in Reservoir – Planning Criteria for the Study

- To assess the fish production from reservoirs, it is essential to follow short-term studies (2-3 years) of collecting data on parameters of limnology, quantitative biology and exploitation by standard methodology as follows:

- ***Morphometric and hydrographic features:*** Water residence time, inflow, outflow and water-level fluctuations, mean depth = volume/area

- ***Physico-chemical parameters:***

Water: temperature, transparency, pH, dissolved oxygen, total alkalinity, total dissolved solids, specific conductivity, nitrates and phosphates.

Soil: Organic-carbon, available nitrogen and available phosphorus.

- ***Quantitative biology:*** Plankton, benthos, periphyton, macrophytes and fish.
- ***Fish populations:*** Commercially important fishes and weed fishes.
- ***Fish yield and fishing effort:*** Species-wise and gear-wise fish landings and fishing effort in terms of crafts, gears and man-hours.

- **Potential yield:** Potential yield can be predicted from primary production, morpho-edaphic index, morpho-drainage index and maximum sustainable yield (MSY).
- **Stocking:** Stocking rate can be calculated on an average growth rate of individual fish and expected production using following formula:
Stocking rate: [Expected production (kg) / Average individual growth rate of fish (kg)] + Allowance due to mortality or escapement (%).

The species spectrum when pitted against available food spectrum in reservoir helps in identifying vacant niches.

This along with a knowledge of productive potential of water-body, facilitates suitable stocking policy with due emphasis on trophic strata in terms of shared, unshared and vacant niches.