Guidelines for Culture-based Fisheries Management in Small Reservoirs in India

Department of Animal Husbandry, Dairying & Fisheries
Ministry of Agriculture
Government of India
Krishi Bhawan
New Delhi - 110 001

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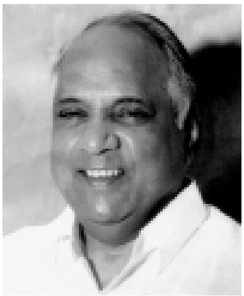

SHARAD PAWAR
MINISTER OF AGRICULTURE
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GOVERNMENT OF INDIA

30th July, 2008

MESSAGE

Sustainable development of the natural resources is the biggest challenge before mankind today. The increasing needs of the growing population have placed larger demands on the natural resources, necessitating a delicate balance between optimum exploitation of the resources and conservation of biodiversity. To achieve this, synergies have to be built between conservation and economic development. India's National Environmental Policy, adopted in 2006, adequately reflects this objective and has also been the guiding principle for integrating environmental concerns in the decision making processes in the country.

Impoundment of the river Narmada and its tributaries has provided the country with a large number of reservoirs, which can be harnessed for producing valuable fish protein for the masses. However, sustainable use of these impoundments for fish production would require sound management norms. The Guidelines for exploitation of fishery resources in the Small, Medium and Large Reservoirs would be valuable tools in the hands of planners and development agencies in achieving the objectives.

These Guidelines have been developed by key experts based on successful case studies not only from India but also from other parts of the world where reservoir fisheries have developed under similar settings. I would urge upon all concerned to adopt these Guidelines for optimum development of the fisheries resources of these water bodies. These Guidelines hold the key to our ability to develop and implement sound management plans for conservation and development of reservoir fisheries not only in the Narmada basin but also in other parts of the country. I am hopeful that sustainable development of the reservoirs can contribute immensely to the fish production of the country and provide livelihoods to the communities dependent on fisheries resources of the reservoirs.

(**SHARAD PAWAR**)

TARUN SHRIDHAR
JOINT SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF AGRICULTURE
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Foreword

The Narmada Control Authority (NCA) is a high-powered body constituted by the Central Government in 1980, to oversee implementation of the Narmada Water Dispute Tribunal Award. In 1987, under the initiatives and direction of the then Prime Minister Late Shri Rajeev Gandhi, the NCA was reconstituted to ensure preparation and timely implementation of the plans and programmes for safeguarding the environment.

Presently, the composition of the NCA includes five Union Ministries *viz.*, Environment & Forests, Power, Social Justice & Empowerment, Tribal Welfare and Water Resources, which are represented by their Secretaries. Besides, the States of Gujarat, Madhya Pradesh and Maharashtra are represented by their Chief Secretary and Secretary in-charge of the Department of Irrigation. In addition, there are four independent members, appointed by the Central Government. The Secretary, Ministry of Water Resources chairs the Authority.

While according clearance to the Sardar Sarovar and Indira Sagar Project from the environmental angle in June 1987, the Ministry of Environment & Forests recognized fish as an important indicator of aquatic ecosystem and, therefore, considered it as a key parameter for detailed Environment Impact Investigations. Subsequently, the Ministry of Agriculture was entrusted with supervision and guidance on the conservation and developmental aspects of fisheries in the Sardar Sarovar Project areas that included the reservoir, its down stream and the vast command area.

The order of clearance issued by the Central Government required preparation and implementation of the plan for conservation and development of fisheries in the impoundments. Subsequently, development plans were received from all the three project States but since they were found to be inadequate from conservational aspects, the States requested for expert advice. This led to the formation of a High Level Expert Group (HLEG) by the NCA. The HLEG observed that though several studies were available on the management of fisheries in the Indian reservoirs, a set of comprehensive guidelines on the conservation and management of the aquatic resources was lacking. The HLEG, therefore decided to frame a set of guidelines for small, medium and large reservoirs, which would be applicable not only for reservoirs under the Sardar Sarovar and Indira Sagar Projects, but also for reservoirs under similar settings in other parts of the country.

Prior to the formulation of the Guidelines, a team of experts led by Dr. Y. S. Yadava, the then Fisheries Development Commissioner in the Ministry of Agriculture, Dr. P. V. Dehadrai, Deputy Director General (Fisheries), Indian Council of Agricultural Research and Dr. Pawan Kumar, Director (Environment) of NCA conducted thorough reviews on the subject, made field visits and also carried out test fishing in selected areas of the Sardar Sarovar Reservoir to have a first hand assessment of the resources. The Guidelines were subsequently prepared by Dr. Yadava with valuable inputs from Dr. V. V. Sugunan, the then Director of the Central Inland Capture Fisheries Research Institute and Dr. S. N. Chatterjee, former Director, Department of Fisheries, Government of Madhya Pradesh and Dr. Pawan Kumar. The Guidelines also drew upon the rich experiences of the Departments of Fisheries of the States of Gujarat, Madhya Pradesh and Maharashtra.

The Guidelines are in two volumes; the first volume deals with fisheries in large and medium reservoirs and the second with fisheries in small reservoirs, including the associated tanks and ponds in the command areas. It is expected that these Guidelines would be handy tools for the concerned agencies for conservation and optimum utilization of the productivity of reservoirs for production of valuable fish protein. This would not only benefit the communities subsisting on the fisheries in the reservoirs but also meet the growing requirements of fish in the country.

(Tarun Shridhar)

Preface

It is now widely accepted that reservoirs constitute one of the prime inland fisheries resources of India. Unlike the rivers, lakes, estuaries and other natural water bodies, which are under the increasing threat of environmental degradation and over-fishing, these man-made lakes offer ample scope for fish yield optimization through adoption of suitable management norms.

Considering the enormous resource size and the untapped production potential, the reservoirs have become the focus of future inland fisheries development in India. However, application of technologies and creation of an enabling governance environment would be needed to achieve the optimum production from the reservoirs.

The emerging Narmada Basin scenario portrays a large number of small, medium and large reservoirs, which along with their use for irrigation and electricity generation will also be ideal resources for production of fish and creation of employment opportunities.

This document gives guidelines for management of small reservoirs, primarily to ensure that the impoundments created under the Narmada River Basin Project are optimally used for fish production. However, they would be equally applicable to small reservoirs elsewhere in India.

Guidelines for culture-based fisheries management given in this document are essentially meant for small reservoirs < 1 000 ha in area. However, all small reservoirs might not be suitable for culture-based fisheries. The conditions suitable for practicing culture-based fisheries are discussed in detail in the document

Guidelines generally carry limitations because of their general character and broad scope and the present guidelines are no exception. In view of the distribution of the small reservoirs across the three States – Gujarat, Madhya Pradesh and Maharashtra – and in varying geo-morphological and ecological settings, it is likely that some of the issues addressed in the Guidelines would need field-level alterations to meet the specific requirements of the impoundment and the user-groups. It is hoped that the managers responsible for fisheries development will take into account such requirements before initiating fisheries development in the reservoirs.

These Guidelines are largely based on the research and development work carried out by the Central Inland Fisheries Research Institute (CIFRI), Barrackpore in optimising fish yield from small reservoirs in the country. The Institute's assistance in preparing these Guidelines is gratefully acknowledged.

Y S Yadava **V V Sugunan**

Acknowledgements

These Guidelines have been prepared at the initiative of the High-Level Expert Group (HLEG) constituted by the Narmada Control Authority (NCA) for conservation and development of fisheries in reservoirs set up under the Sardar Sarovar and Indira Sagar projects. The NCA also provided funds for preparation of the Guidelines.

The activities of the HLEG were guided by the Department of Animal Husbandry, Dairying & Fisheries (DAHD&F), Ministry of Agriculture, Government of India, and coordinated by the Environment Wing of the NCA. We express our sincere gratitude to Shri Ajay Bhattacharya, former Joint Secretary (Fisheries), DAHD&F and to Shri Tarun Shridhar, Joint Secretary (Fisheries) who have provided valuable advice and leadership in the formulation of the Guidelines.

We are indebted to Dr. Pawan Kumar, Director (Environment) of the NCA, for organizing and coordinating the effort and providing assistance at every stage. We would also like to place on record our thanks to Dr. P. V. Dehadrai, former Deputy Director General (Fisheries), Indian Council of Agricultural Research, as well as Dr. S. N. Chatterjee and Dr. G. P. Dubey, both former Directors of the Department of Fisheries, Government of Madhya Pradesh, for their valuable assistance in accomplishing this professionally challenging task.

We also acknowledge the contributions of Shri M. K. R. Nair, Fisheries Development Commissioner, DAHD&F and Dr. Musharaf Ali, Assistant Commissioner (Fisheries), DAHD&F in finalization of the Guidelines.

Many agencies and professionals have shared their valuable experiences with us, which helped us in preparing this document. While it is not feasible to acknowledge all contributions personally, we place on record our sincere gratitude for their rich and varied experience and professional insight that enabled us to accomplish this task.

Finally, our special thanks to Shri M. K. Sinha, Member (Environment & Rehabilitation), NCA for his advice, unstinted support and constant encouragement in bringing out these Guidelines.

Y S Yadava

V V Sugunan

Contents

1. 0 Introduction

Reservoirs are defined as man-made impoundments created by constructing dams or other barricades across rivers or streams (Sugunan, 1995). India has more than 3 million ha of reservoirs distributed under divergent geo-climatic, morphometric and edaphic environments. These are classified generally as small (<1 000 ha), medium (1 000 to 5 000 ha) and large (>5 000 ha). Based on the study carried out by the Food and Agriculture Organization of the United Nations (FAO) in 1995, the distribution of small, medium and large reservoirs in India is given below (Table 1):

Table1: Distribution of small, medium and large reservoirs in 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, V. V., 1995

India being a country of continental proportions, its reservoirs are spread over various types of terrains, and soil types exposed to diverse climatic conditions. They receive drainage from a variety of catchment areas. Fish yields from different categories of reservoirs- small, medium and large- have been estimated at about 50 kg/ha/yr, 12 kg/ha/yr and 11kg/ha/yr respectively, the average being about 20 kg/ha/yr. This yield is very low in comparison to countries, such as China (>800 kg/ha/yr), Sri Lanka (>300 kg/ha/yr) and Cuba (>100 kg/ha/yr). The present low levels of production from the reservoirs is due to many reasons: lack of fish seed for stocking, inappropriate gear and craft, poor landing and marketing channels, absence of closed season and other management measures like weak cooperatives, stranglehold of middle-men, etc.

There are various estimates about the total area under reservoirs in India. The detailed study made by FAO in 1995 has estimated a total of 19 370 reservoirs in the country with a total area of 3.15 million ha (Sugunan, 1995). However, the Handbook on Fisheries Statistics (2006) of the Ministry of Agriculture (Department of Animal Husbandry, Dairying & Fisheries), Government of India gives an estimate of 2.91 million ha under reservoir fisheries.

Contrary to the common perception, reservoir fisheries is neither capture fisheries nor culture fisheries. Fisheries management of reservoirs is based on the principles of 'enhancement', which is defined as a range of management practices/processes by which qualitative and quantitative improvement is achieved from water bodies by exercising specific management options. This is something intermediate between culture and capture fisheries. Enhancement *inter alia* includes 'culture based fisheries (stock and recapture)', 'stock enhancement (enhanced capture fisheries)', 'species enhancement (introduction of species)', 'environmental enhancement (fertilizing water bodies)', 'management enhancement (introducing new management options)' and ‘enhancement through new culture systems (cage culture, pen culture, fish aggregating devices or FADs, etc)’. Reservoirs offer scope for one or more forms of enhancement. The most suitable management strategy for a particular reservoir is chosen, based on its morphometric, edaphic and biological characteristics.

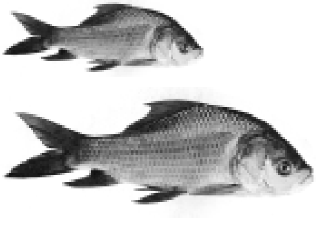
The two most common forms of enhancement followed in Indian reservoirs are culture-based fisheries and stock enhancement. Of these, culture-based fisheries is generally practiced in the small reservoirs.

Small reservoirs

In contrast to large multi-purpose reservoirs, the small irrigation reservoirs, constructed on small intermittent water courses, serve to capture the surface runoff for its abstraction to meet the seasonal irrigation demands. Many impoundments have multiple uses. They are built for the primary purposes of irrigation and soil and water conservation. Experience has shown that these water bodies offer immense scope for various kinds of enhancements leading to higher productivity and income generation for the local communities. They can undoubtedly contribute significantly to country’s inland fish production, if managed scientifically.

Small reservoirs in India, which cover nearly 1.5 million ha, form one of the most important inland fisheries resources of the country on account of the large resource size and the huge untapped production potential. They have the advantage of enabling quick enhancement of yield due to their higher biological productivity and easy maneuverability of fish stocks. The available technologies offer possibilities for achieving higher production levels, although the national yield in such small water bodies is about 50 kg/ha. By virtue of their important role in promoting fisheries development through mass participation of local communities, the small reservoirs assume special significance in inland fisheries development.

The subsequent chapters of this document deal mainly with the practices of culture-based fisheries in small reservoirs in India. Some other modes of enhancement, which could be adopted in small reservoirs, are also described. However, the methodologies for stock enhancement in medium and large reservoirs are not discussed in this document. Description of management norms for such reservoirs is given in ‘Guidelines for Fisheries Management in Medium and Large Reservoirs in India (Yadava and Sugunan, 2009).



2. 0 Resources

The small irrigation impoundments are as nondescript as they are ubiquitous and the atomistic nature of these water bodies makes the task of assessing their fisheries potential more tedious than the resource assessment of other sectors where the units are situated at more identifiable locations. The problem is further confounded by ambiguities in the nomenclature adapted by some of the peninsular States, especially in the use of the word 'tank'.

2.1 Nomenclature of tanks and reservoirs

The word 'tank' is often loosely defined and used in common parlance to describe some of the small irrigation reservoirs. Thus, a large number of small man-made lakes are designated as tanks, thereby precluding them from the estimates of reservoirs. There is no uniform definition for a tank. In the eastern States of Orissa and West Bengal, ponds and tanks are interchangeable expressions, while in Andhra Pradesh, Karnataka and Tamil Nadu, tanks refer to a section of irrigation reservoirs, including small and medium-sized water bodies.

David *et al.* (1974) defined the peninsular tanks as water bodies created by dams built of rubble, earth, stone and masonry work across seasonal streams, as against reservoirs, formed by dams built with precise engineering skills across perennial or long seasonal rivers or streams, using concrete masonry or stone, for power supply, large-scale irrigation or flood control purposes. Irrespective of the purpose for which the lake is created and the level of engineering skill involved in dam construction, both the categories fall under the broad purview of reservoirs, *i.e.* man-made lakes created by artificial impoundment of surface flow. From limnological and fisheries points of view, the distinction between small reservoirs and tanks seems to be irrelevant. Moreover, numerous small reservoirs fitting exactly into the description of the Southern Indian tanks are already enlisted as reservoirs in the rest of the country. Anomalies in nomenclature, especially with regard to the small reservoirs, have been removed by bringing some of the large (>10 ha) irrigation tanks under the fold of reservoirs.

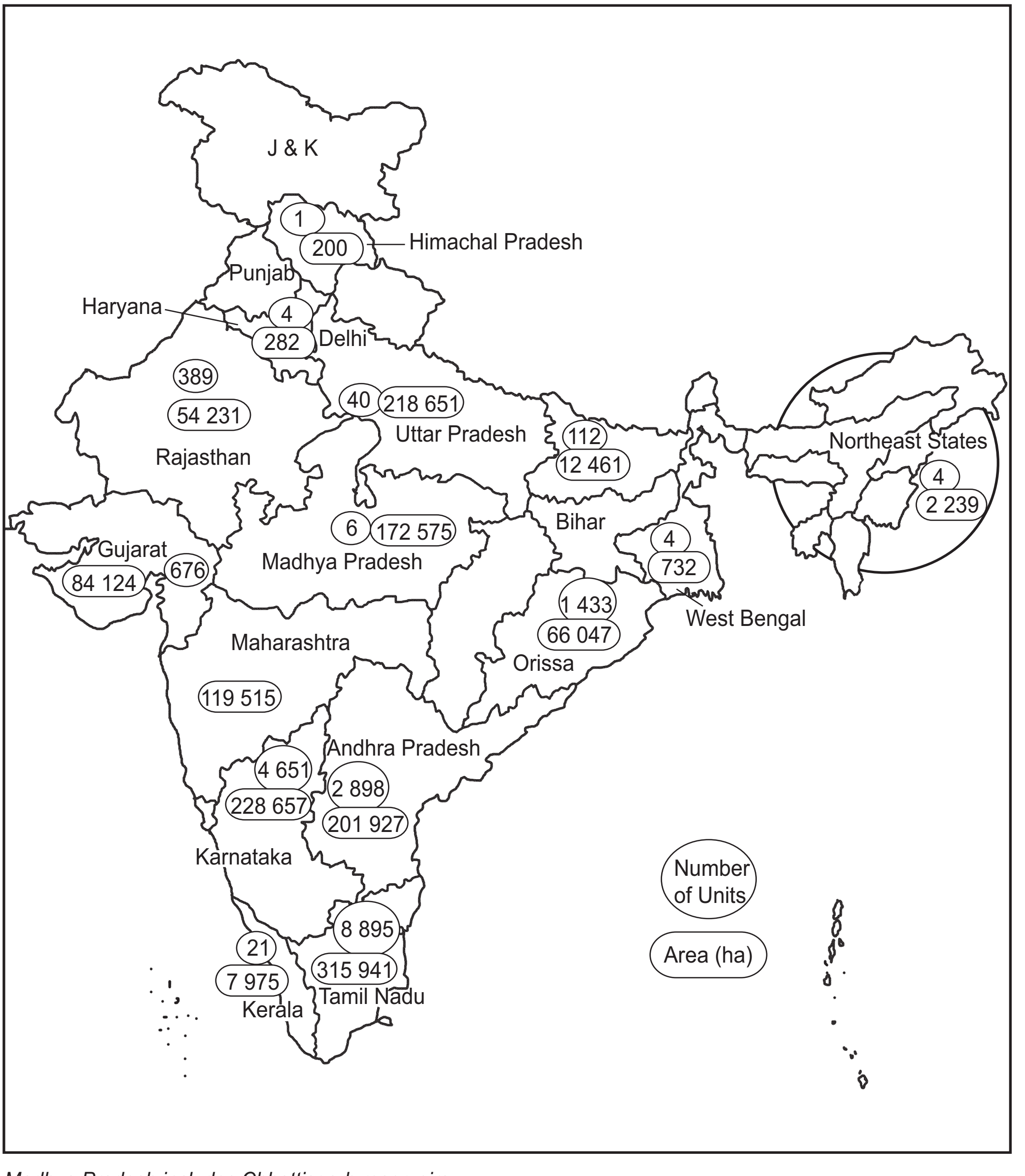
2.2 Distribution

India has 19 134 small reservoirs with a total water surface area of 1 485 557 ha (Fig. 1; Table 2). The State of Tamil Nadu accounts for the highest number (8 895) and area (315 941 ha) of small reservoirs, followed by Karnataka (4 651 units and 228 657 ha) and Andhra Pradesh (2 898 units and 201 927 ha).

2.3 Fish production trends in small reservoirs

Fish production trends in respect of 291 small reservoirs in India have been documented. Fish yield figures of small reservoirs in Andhra Pradesh, as given by the State Fisheries Department are very impressive (average 188 kg/ha) followed by those of Kerala, Madhya Pradesh, Tamil Nadu and Rajasthan in the range of 46.43 to 53.50 kg/ha. The national average yield is estimated at 49.9 kg/ha (Table 3).

Fig. 1: Distribution of small reservoirs in India



Madhya Pradesh includes Chhattisgarh reservoirs.
Uttar Pradesh includes Uttarakhand reservoirs.
Bihar includes Jharkhand reservoirs.
Northeast States include Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura.

Table 2: 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			**	119 515
Bihar	112	12 461			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 States	4	1 639		600	4	2 239
Total	**2 331**	**551 695**	**16 803**	**933 862**	**19 134**	**1 485 557**

Source: Sugunan, V. V., 1995

* Not exhaustive; ** Not available

Table 3: Fish production trends in small reservoirs

State	Number	Production (tonnes)	Average yield (kg/ha)
Tamil Nadu	52	760	48.50
Uttar Pradesh	31	168	14.60
Andhra Pradesh	37	2 224	188.00
Maharashtra	6	72	21.09
Rajasthan	78	970	46.43
Kerala	7	118	53.50
Bihar	25	22	3.91
Madhya Pradesh	2	24	47.26
Himachal Pradesh	-	-	-
Orissa	53	349	25.85
Total	291		
Average			**49.90**

Source: Sugunan, V. V., 1995

2.4 Distinguishing features of small, medium and large reservoirs

A set of broad guidelines for distinguishing small reservoirs, which are suitable for culture-based fisheries, from the medium and large reservoirs that are primarily used for stock enhancement are given in Table 4. In addition to their physical attributes, impoundments are defined by factors including species diversity, fertility and structural complexity of the aquatic habitat. The goal of fishery management is to control these factors to produce a harvestable surplus while maintaining a dynamic equilibrium within the ecosystem.

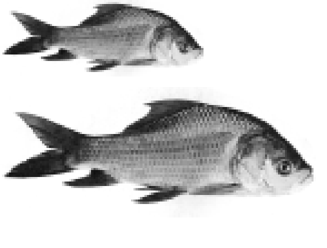


Table 4: The broad distinguishing features of small, medium and large reservoirs

Small reservoirs (for culture-based fisheries)	**Medium and large reservoirs (for stock enhancement)**
Single-purpose reservoirs mostly for minor irrigation.	Multi-purpose reservoirs for flood-control, hydro-electric generation, large-scale irrigation, etc.
Dams neither elaborate nor very expensive. Built of earth, stone and masonry work on small seasonal streams.	Dams elaborate, built with precise engineering skill on perennial or long seasonal rivers. Built of cement, concrete or stone.
Shallow, biologically more productive per unit area.	Deep, biologically less productive per unit area.
May dry up completely in summer. Notable changes in the water regime.	Do no dry up completely. Changes in water regime slow. Maintain a conservation-pool level (*i.e.* dead storage level).
Sheltered areas absent.	Sheltered areas present by way of embayments, coves, etc.
Shoreline not very irregular. Littoral areas with a gentle slope.	Shoreline more irregular. Littoral areas mostly steep.
Oxygen mostly derived from photosynthesis. No stratification and significant wave action.	Thermal and chemical stratification can occur. Oxygen derived from significant wave action and photosynthesis.
Breeding of commercially important species not commonly observed.	Breeding of commercially important species mostly occur in the reservoir.
Trophic burst and depression phases do not occur.	Trophic burst and depression phases do occur.
Complete fishing possible. Fish stocks have to be built through annual stockings.	Complete fishing not possible. Recruitment through natural breeding possible.
Correlation between stocking rate and catch per unit effort possible.	Correlation between stocking rate and catch per unit effort not possible.
Low predation pressure. Total elimination of predators also possible.	Predation pressure can be high. Total elimination of predators not possible.
Culture-based fishery models applicable as recruitment and mortality (both fishing and natural mortality) are known.	Capture fisheries models applicable as natural mortality and recruitment can only be indirectly estimated.

3.0 Fish production processes in small reservoirs

The objective of fishery management in small reservoirs is to achieve high fish production on a sustainable basis. The fish yield is partly a function of abiotic and biotic factors and partly the management steps. The degree of management that can be exercised to achieve the optimum yield would depend upon a number of factors such as:

(i) Inherent capacity of the water body to produce primary fish food organisms;

(ii) Food chain;

(iii) Growth rate of the stocked fish; and

(iv) Survival rate of stocked fish.

3.1 Inherent capacity of the water body to produce primary fish food organisms

Capacity of the reservoir to produce phytoplankton (the primary producers) depends on a number of abiotic and biotic variables. The abiotic variables include climatic, morphometric and edaphic factors.

Climatic variables: The climatic factors have a profound effect on the physico-chemical attributes of soil and water and nutrient dynamics in the lake basin. The temperature regimes of reservoirs in Northern India exhibit wider fluctuations compared to those of Southern India.

Morphometric variables: Area, mean depth and regularity of shoreline are the most significant morphometric measurements having a significant bearing on the productivity of a reservoir. These influence the capacity of the water body to produce phytoplankton and providing conducive habitat for fish.

Edaphic variables: The edaphic factors affect the supply of dissolved nutrients in the reservoir water. The extent of drainage area, its rate of erosion and runoff are important in limiting the supply of nutrients to the lake. Soil basin quality influences the reservoir productivity to a great extent (Table 5).

Temperature is one of the most important factors affecting fish growth. Growth increases with increasing temperature to a maximum and then declines rapidly. Within these limits, metabolism and food requirements increase with increasing temperature. As water temperature increases, metabolic rate and oxygen demand also increase. On the other hand, as temperature increases, the oxygen carrying capacity of water decreases, making less oxygen available for increased metabolic activity.

The chemical composition of water varies considerably among regions. Alkalinity and pH are linked to photosynthesis and affect the amount of carbon dioxide available for photosynthesis and hence fish production.

Table 5: Physico-chemical features of reservoirs in India
(Range of values)

Parameters	Overall range	Productivity		
		Low	Medium	High
A. WATER				
pH	6.5 – 9.2	< 6.0	6.0 – 8.5	> 8.5
Alkalinity (mg/l)	40 – 240	< 40.0	40 – 90	> 90.0
Nitrates (mg/l)	Tr.– 0.93	Negligible	Up to 0.2	0.2 – 0.5
Phosphates (mg/l)	Tr.– 0.36	Negligible	Up to 0.1	0.1 – 0.2
Specific conductivity (µmhos)	76 – 474	–	Up to 200	> 200
Temperature (^{0}C)	12.0 – 31.0	18	18 – 22	> 22
(with minimal stratification: i.e. > 5^0 C)				
B. SOIL				
pH	6.0 – 8.8	< 6.5	6.5 – 7.5	> 7.5
Available P (mg/100g)	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 (percent)	0.6 – 3.2	< 0.5	0.5 – 1.5	1.5 – 2.5

(After Jhingran and Sugunan, 1990); Tr. – Traces

Oxygen dissolved in water is a function of temperature and altitude. Tolerance to low levels of dissolved oxygen is species dependent. However, many fish exhibit slow growth when oxygen levels fall below 5 mg/1 (or 5 ppm) for extended periods.

The chemical properties of water in reservoirs are a reflection of the properties of bottom soil. When oxygen supply falls short in mud layers, which are not well aerated, the decomposition of organic matter becomes slow. This low accumulation of products of decomposition and the presence of partially oxidized compounds and short chain fatty acids make the soil strongly acidic. The bacterial action is reduced and productivity lowered. pH also influences transformation of soluble phosphates and controls the absorption and release of essential nutrients at soil-water interface. A slightly alkaline soil (pH 7.5) is considered optimal for fish production. Productive soils range mostly between slightly alkaline to slightly acidic (7.5-6.5) in reaction.

Organic matter in the reservoir ecosystem comes from both within (autochthonous) and outside (allochthonous) sources. It acts as an actual food source for higher levels in the food chain and also as a substrate for bacterial growth and growth of other micro-organisms. Primary production by the photosynthetic phytoplankton, the base of food chain, is the major autochthonous source of organic production. The allochthonous nutrients that come along with runoff from the watershed and inflow are more significant, both qualitatively and quantitatively.

Biotic variables: The biotic variables comprise the qualitative and quantitative abundance, diversity and distribution of biotic communities such as phytoplankton, zooplankton, benthos, periphyton, macro-vegetation and littoral fauna and flora. These impact fertility of the environment; diversity of fish populations in terms of structure and function; foraging efficiency of predators in predator-prey systems; modification of aquatic habitat; and manipulation of population through planned fishing mortality. Aquatic weeds found in shallow water bodies often compete with beneficial plankton for nutrients, interfere with harvest and contribute to oxygen depletion. A good understanding of the biotic communities would allow the fishery manager to make the right stocking decisions to enhance fish yields.

3.2 Food chain

In an aquatic ecosystem, primary carbon is synthesized by phytoplankton, the primary producers. The energy fixed by these primary producers is transformed to higher trophic levels through a complex food chain so that a fraction of the energy reaches the level of fish that can be harvested (Fig. 2). The efficiency of the food chain is determined by the rate of this energy transfer. In a shorter food chain, the energy is more efficiently transformed into higher trophic levels and, therefore, fish feeding on phyto or zooplankton are considered more efficient in converting the primary energy into fish flesh.

Although the climatic, morphometric and edaphic factors help reservoir productivity, total fish output also depends on the performance of the stocked fish in terms of growth and survival. This leads us to the concepts of density- dependent growth and size- dependent mortality in culture-based fisheries, which are briefly described below.

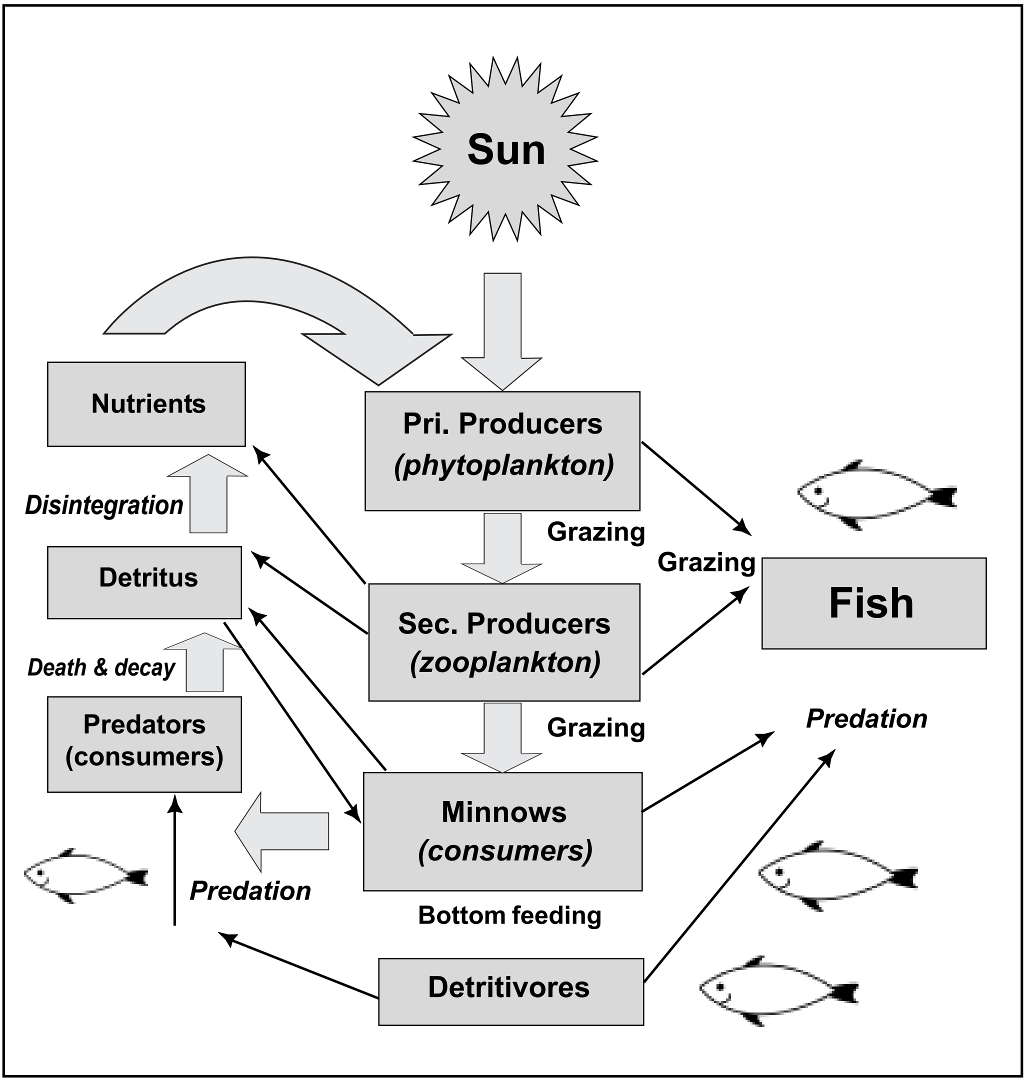
3.3 Growth rate of stocked fish

As the stocked fishes share the common pool of food reserves in the water body, the stocking density should be at an optimum. If excess fish are stocked, the individual fish may not get enough food and their growth will be sub-optimal. Similarly, understocking might result in non-utilization of all natural fish food available in water. Thus, the growth of fish in a culture-based fishery is a function of stocking density.

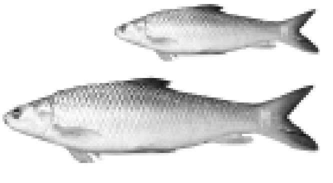
3.4 Survival rate of stocked fish

The ability of a fish to escape predators and survive other adversities like diseases and hostile environment is directly related to the age, at least during the early phase of its life cycle. This is due to the advanced development of organs, better immune system and ability to swim faster to escape predators. Thus, the larger the size of fish stocked, the better their chances of survival. Once the rates of density- dependent growth and size- dependent mortality factors are determined, it will be easier to arrive

Fig. 2: Food chain in an aquatic ecosystem



at the stocking density and the size at stocking. Other important factors to be considered in culture-based fisheries management include the optimum size at capture and the quantum of fish to be harvested, both of which can be manipulated through maneuvering fishing effort in qualitative and quantitative terms.



4.0 Fisheries management

Management of culture-based fisheries involves stocking of fish into the reservoir, allowing the stock to grow utilizing the natural fish food resources and harvesting them at an appropriate size. Therefore, the number of fish to be stocked, the size at which they are stocked, the period of growth and the size at which they are harvested play a key role in the success of culture-based fisheries in small reservoirs (Fig.3). In this regard, the key management decisions to be made are:

- (i) Estimation of fish yield potential;
- (ii) Selection of fish species for stocking;
- (iii) Stocking rate and size; and
- (iv) Period of growth and size at harvesting;

4.1 Estimation of fish yield potential

It is essential to assess the fish yield potential of the reservoir for formulating appropriate stocking strategies, especially stocking density. Fish yield potential of the water body is determined by its biotic and abiotic characteristics.

Several methods are in vogue to assess the fishery potential of small reservoirs by deriving equations based on area, depth, catchment area and the chemical parameters of soil and water. Among them, the morpho-edaphic index (MEI) method is widely accepted. This method combines the morphometric as well as chemical parameters and is most suited to the Indian reservoirs, considering that the ionic composition and depth are important parameters under Indian conditions. This method involves calculation of MEI as:

$$MEI = \frac{\text{Specific conductivity } (\mu\text{mhos/cm})}{\text{Mean depth (m)}}$$

Fish yield potential is then calculated using the formula:

Fish yield in kg/ha/yr (C)= 0.9897 MEI $^{1.3888}$ (Sugunan *et al.*, 2002).

An illustration of calculating MEI and fish yield potential is given in Box 1.

Box 1: Calculating MEI & fish yield potential

Specific conductivity = 300 µmhos/ cm

Mean depth = 5.0 meters

$$MEI = \frac{\text{Specific conductivity}}{\text{Mean depth}} = \frac{300}{5.0} = 60$$

Fish yield potential

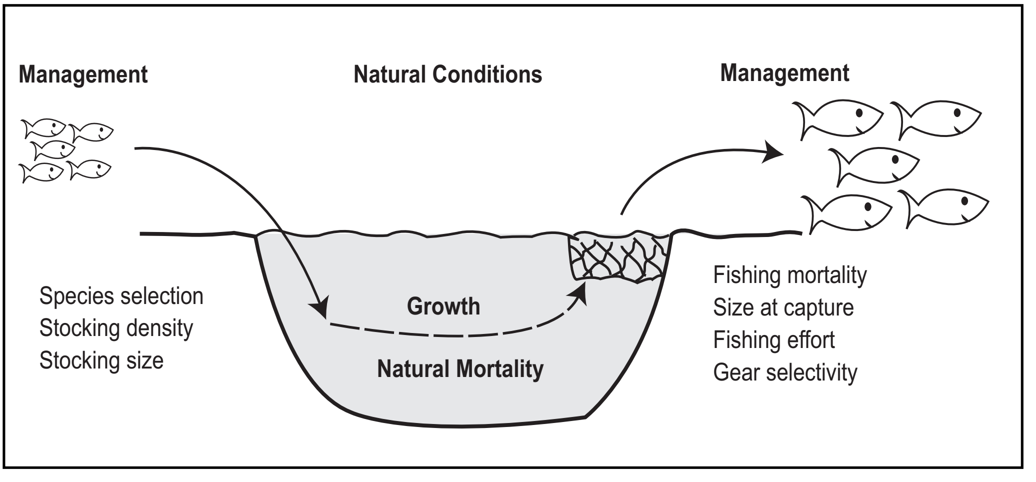
$C = 0.9897\ MEI^{1.3888}$

$= 0.9897 \times 60^{1.3888}$

$= 0.9897 \times 295$

= 292 Kg/ha/ yr

Fig. 3: Diagrammatic representation of processes involved in culture-based fisheries



4.2 Selection of species for stocking

The selection of species for stocking is guided by the chances of the stocked species to thrive in the reservoir and effectively utilize the food resources and converting them into fish flesh at the quickest possible time.

Basic principles that govern selection of species for stocking are:

- The stocked species should find the environment suitable for maintenance and growth.
- It should be a quick growing species with high efficiency of food utilization (shortest food chain).
- The size of the stock should be chosen with the expectation of getting the desired results.

One of the important aspects of stocking policy is to know the amount of food available per individual in the environment. This aspect has a considerable bearing on stocking rate and subsequently also determines production. In multi-species systems, fish can occupy different niches where competition is avoided or at least minimised. Species competition for space and food can occur if niches overlap for any life history stage of the stocked species or with those already present in the reservoir ecosystem. In the small reservoirs under consideration, all the three Indian major carps (*Labeo rohita, Catla catla* and *Cirrhinus mrigala*), the exotic carp (*Cyprinus carpio* or common carp) and the freshwater prawn (*Macrobrachium rosenbergii*) can be ideal candidate species (Fig. 4).

4.3 Stocking rate and size

Stocking rates need to be fixed for individual water bodies or a group of them sharing common characteristics such as size, presence of natural fish populations, predation pressure, fishing effort, possible stock loss, minimum marketable size and multiplicity of water use. The number of fish to be stocked is based on the growth of individual fish and the total possible yield of the reservoir. In other words, it is a function of the total biomass of fish and the weight of the individual fish at harvest.

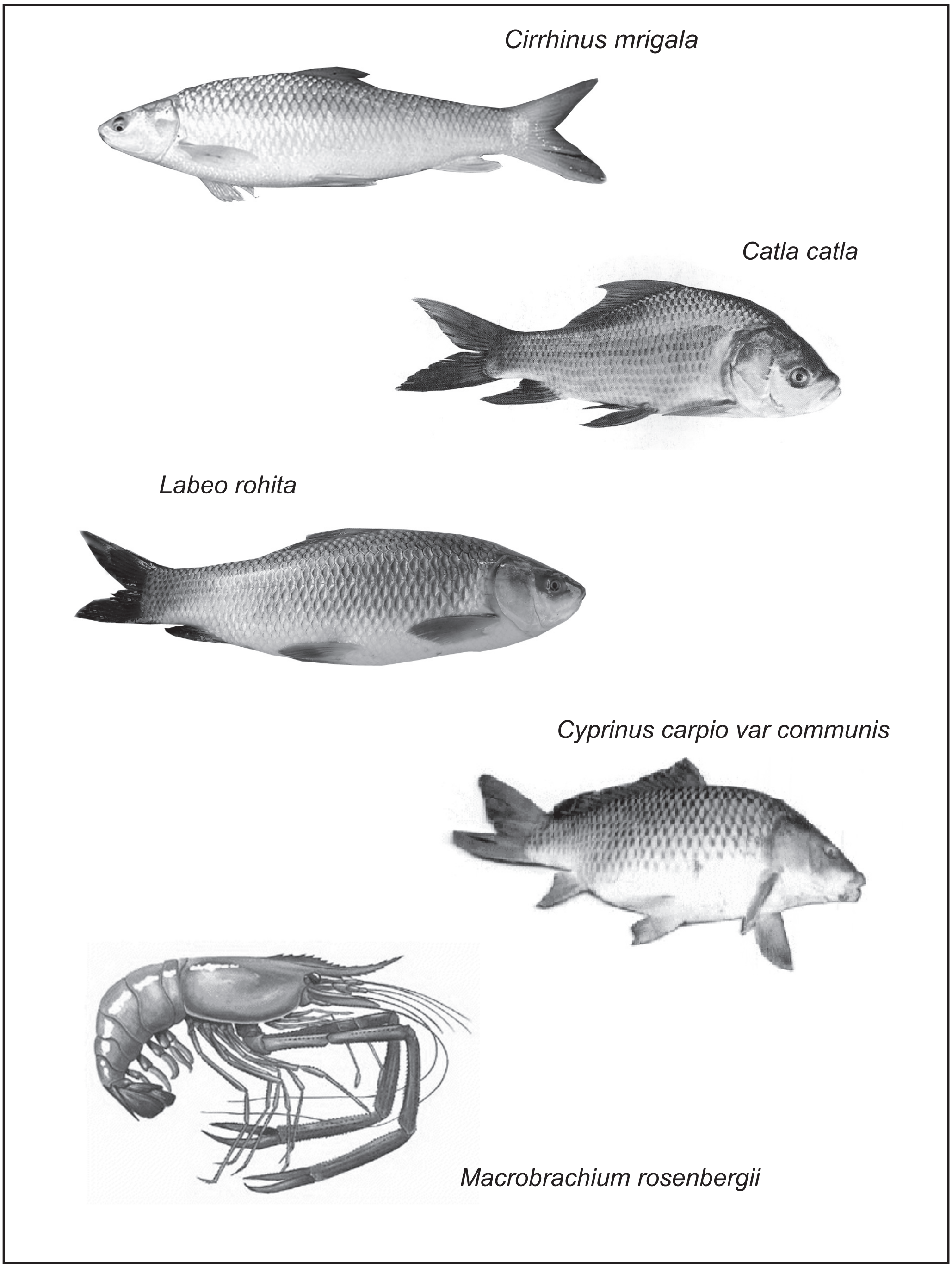
The main consideration in determining the stocking rate is growth of individual species stocked, the mortality rate, size at stocking and the growing time. A formula to calculate the stocking rate (Welcomme, 1976) is given below.

$$S = \{qP/W\}\, e^{-z\,(t_e - t_o)}$$

S - Number of fish to be stocked (in number/ha); P - Natural annual potential yield of the water body; Q - The proportion of the yield that can come from the species in question; W - mean weight at capture; t_e - age at capture; t_o - age at stocking; -z - Total mortality rate.

P can be estimated through MEI method and the range of mortality rates can be found out from the estimated survival rate.

Fig. 4: Important candidate species for stocking in small reservoirs in India



However, the calculation of this natural mortality involves skill in population dynamics. To enable the fishery manager to estimate the stocking rate, a simplified Table (after Welcomme, 1976) is provided (Table 6):

Table 6: Calculated stocking density at different levels of mortality

Annual percent survival	-Z	Estimated number of fish to be stocked (number/ha)
50	0.7	405
37	1.0	739
22	1.5	2 000
13	2.0	5 500

An illustration to calculate the stocking rates in two situations – catla, 100 percent and catla and rohu combination, 50 percent each – is given in Box 2. The application of the above formula is based on the assumption that breeding of the stocked population is insignificant and, therefore, it applies mainly to total cropping situations *i.e.* in which fish are caught below their minimum size for maturity and where natural reproduction does not take place.

Box 2: Illustration to calculate stocking rates		
Species combination	**Catla 100%**	**Catla 50%; Rohu 50%**
Species to be stocked	**Catla**	**Catla***
Estimated yield potential:	**200 kg/ha**	**200 kg/ha**
Expected mortality:	**50% (-z =0.7)**	**50% (-z =0.7)**
$t_e - t_o$:	**1 year**	**1 year**
Expected individual growth;	**0.5 kg**	**0.5 kg**
Number of fingerlings to be stocked: (no/ha)	$S = \{qP/W\}\ e^{-z\,(t_e - t_o)}$ $= \{1x200/0.5\}\ e^{0.7} x\ 1$ $= \{200/0.5\}\ e^{0.7}$ $= \{400\}\ e^{0.7}$ **= 400x2.0137** **= 805/ha**	$S = \{qP/W\}\ e^{-z\,(t_e - t_o)}$ $= \{0.5x200/0.5\}\ e^{0.7} x\ 1$ $= \{100/0.5\}\ e^{0.7}$ $= \{200\}\ e^{0.7}$ **= 200x2.0137** **= 402/ha**

****** The number of Rohu to be stocked can be calculated similarly.***

The methodologies for calculating stocking rate as described above are only indicative. Higher stocking densities might be possible due to increased nutrient status of the reservoir through extraneous inputs (*e.g.* higher organic loading), larger catchment area feeding the water body and other favourable conditions (*e.g.* absence of predatory species, etc). In such cases, yield rates much higher than what is calculated through the formula is possible.

Stocking size: The size of stocking is important from economic as well as biological point of view. Biologically, the larger the fish stocked the better its chances of survival and thus even lesser number of individuals can be stocked. But growing fish to fingerling size is an expensive proposition and it is economically expedient to stock at a lower size in larger numbers. This can be done only when the ecosystem is free from or has lesser number of predators. The discretion of the manager is, therefore, important to determine the size at stocking. In any case, fingerlings of > 100 mm size are considered to be safe and give the best results. In data-deficient situations, stocking of 80 -100 mm size fingerlings is always recommended.

4.4 Period of growth and size at harvesting

Normally, the stocks are replenished annually in small reservoirs and thus the growth cycle is annual and the stocked fish grow to 0.7 -1.0 kg at harvest depending upon the water quality and species stocked. However, fish can grow to a harvestable size (starting from 0.5 kg onwards) in a culture-based fishery in 6 - 8 months. Thus, the seasonal reservoirs that retain water up to 6 - 8 months can be used for culture-based fisheries. However, it must be borne in mind that the fish harvested at a lower size will give higher yield rate in terms of kilogram per hectare. Therefore, depending upon the requirements and acceptance of the market, the size at harvest can be determined.

Staggered stocking and harvesting: The practice of staggered stocking and harvesting is known to yield better efficiency and economic returns. It allows replenishment of harvested stock at regular intervals and thereby optimum utilization of the inherent productivity of the water body. Further, it also permits catching of fish only above certain size and voluntary release of smaller fishes back into the reservoir. Higher level of motivation and awareness among fishers is required for practicing this method. In several small reservoirs of Tamil Nadu, staggered stocking and harvesting is yielding better results and is, therefore, recommended for adoption. However, caution should be exercised to avoid overstocking and subsequent low growth rate due to reduced availability of food.

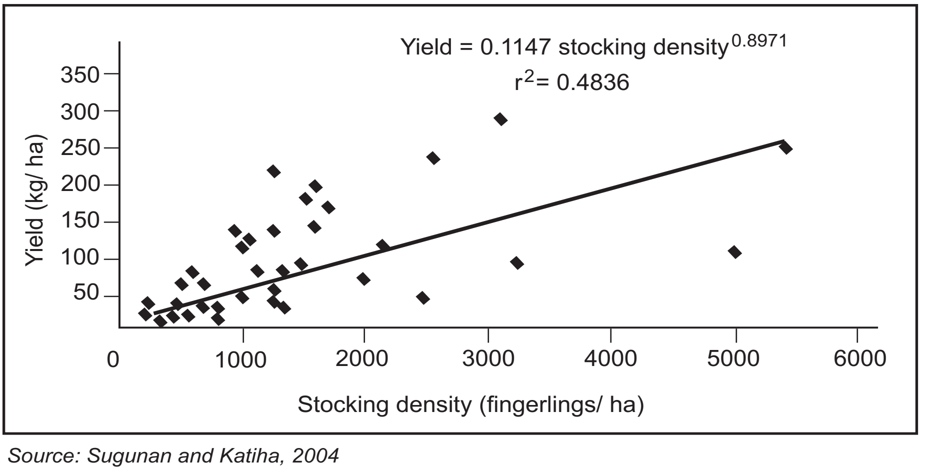
Stock loss: Loss of juvenile and adult fish through the overflowing spillways poses a serious problem in small reservoirs. The situation is further worsened by heavy escape of fingerlings and adults through irrigation canals. Development of fisheries in such water bodies, therefore, requires suitable screening of the spillway and the canal mouth. Such protective measures have already been installed in some of the reservoirs. They are paying dividends by enhancing fish yield from the reservoir. However, caution is to be exercised to see that the screens across spillway do not get

clogged during flood season, which may threaten to damage the dam. In some of the reservoirs fishes have also been observed to move up the spillway into the reservoir whereas in others the spillways provide an insurmountable barrier to fish moving up the dam. To minimise losses by way of escape of fish through spillway and canal, it would be an economic proposition to have an annual cropping policy so that the reservoir is stocked in September - October and harvested by June end. However, this depends on the growth of fish and the general productivity of the water body.

4.5 Seed production infrastructure

Stocking is the key to a successful culture-based fisheries regime. Scientific studies have shown that fish yield is significantly correlated to stocking (Fig.5). In India, many instances of low yield from reservoirs can be attributed to non-compliance of stocking size and numbers. The established carp seed industry in the country caters largely to the aquaculture sector and the huge demand from reservoirs often remains unmet. This calls for creating an adequate supply chain for fingerlings for stocking in reservoirs. In areas where large numbers of small reservoirs are taken up for development, a cluster approach would be ideal and also cost-effective. Wherever land-based nurseries are not available, pen and cage culture for *in-situ* raising of seed material would be most desirable.

Fig. 5: Relationship between stocking density and fish yield in reservoirs



Source: Sugunan and Katiha, 2004

4.6 Post-harvest, marketing arrangements and policy support

Inadequate marketing channels and marketing infrastructure also act as disincentives for the community to produce more fish, as small reservoirs are mostly located in hinterlands away from main markets. Therefore, accessing markets is an essential pre-requisite for the success of small reservoir fisheries. The emerging new retail marketing opportunities in India can be suitably utilized to the advantage of fishers. Proper arrangements, including post-harvest processing and value addition, will go a long way in improving production, and these aspects need to be integrated into the management/processes. Similarly, collective arrangements for marketing can give producers greater bargaining power and also help in setting up of more cold-chains, wherever required.

In the absence of sound policy support for reservoir fisheries sector, the availability of public finance is also limited. Once this problem is addressed, there may be enough money to create the right infrastructure and to loosen the hold of usurious moneylenders on the reservoir fisher community.

5.0 Impact of culture-based fisheries in small reservoirs

Success in management of culture-based fisheries in small reservoirs depends more on recapturing the stocked fish rather than on their building up a population. The smaller water bodies have the advantage of easy stock monitoring and manipulation. Thus, the smaller the reservoir the better is the chance of success in the stock and recapture process. In fact, an imaginative stocking and harvesting schedule is the main theme of fisheries management in small, shallow reservoirs. The basic tenets of such a system, as explained in the previous chapters, largely involve:

- Selection of the right species, depending on the fish food resources available in the system.
- Determination of stocking density on the basis of production potential, growth and mortality rates.
- Proper stocking and harvesting schedule, including staggered stocking and harvesting, allowing maximum grow out period, taking into account the critical water levels.
- In case of small irrigation reservoirs with open sluices, the season of overflow and the possibilities of water level falling too low or completely drying up, are also to be taken into consideration.

Aliyar reservoir in Tamil Nadu, where culture-based fisheries were tried by the CIFRI, is a standing testimony to the efficacy of staggered stocking. The salient features of the management options adopted in Aliyar were:

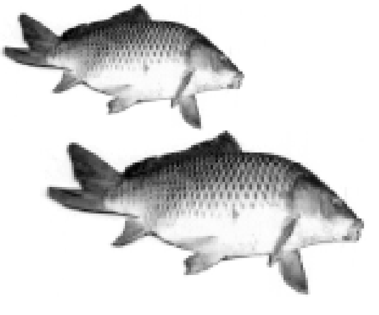
- stocking limited to Indian major carps (earlier other slow-growing carp species were stocked);
- increasing the size of stocking to 100 mm and above;
- reducing the stocking density to 235 - 300/ha (earlier rates were erratic ranging between 500 - 2 500/ha);
- staggering the stocking; and
- regulating mesh size and banning the catch of Indian major carps < 1 kg in size.

A direct result of the above management practice was an increase in fish production from 1.67 kg/ha in 1964 - 65 to 194 kg/ha in 1990.

Table 7: High yields obtained in small reservoirs due to management based on stocking

Reservoir	State	Stocking rate (number/ha)	Yield (kg/ha)
Aliyar	Tamil Nadu	353	194
Tirumoorthy	- do -	435	182
Meenakara	Kerala	1 226	107
Chullar	- do -	937	316
Markonahalli	Karnataka	922	63
Gulariya	Uttar Pradesh	517	150
Bachhra	- do -	763	140
Baghla	- do -	-	102
Bundh Beratha	Rajasthan	164	94

Successful stocking has also been reported from a number of other small reservoirs in India (CIFRI, 2000). In Markonahalli, Karnataka, on account of stocking the percentage of major carps has increased to 61 percent and the yield increased to 63 kg/ha. Yields in Meenakara and Chullar reservoirs in Kerala have increased from 9.96 to 107.7 kg/ha and 32.3 to 275.4 kg/ha respectively through sustained stocking. In Uttar Pradesh – Bachhra, Baghla and Gulariya reservoirs registered steep increase in yield through improved management with the main accent on stocking. An important consideration in Gulariya reservoir was to allow maximum grow out period between the date of stocking and the final harvesting, *i.e.* before the water level went below the critical mark. The possible loss due to the small size at harvest was made good by the numbers. Bundh Beratha reservoir in Rajasthan, stocked with 100 000 fingerlings a year(164/ha) resulted in a fish yield of 94 kg/ha; 80 percent of which comprised catla, rohu and mrigal (Table 7).



6.0 Modeling approach in culture-based fisheries in small reservoirs

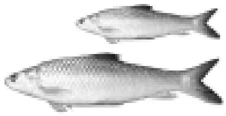
Recent studies based on modeling approach have opened up new avenues for culture-based fisheries in small reservoirs. Notwithstanding the fact that studies on the population dynamics based on modeling approach demand higher levels of inputs in the form of money and trained manpower, an insight into the modeling approach will help the manager in understanding the ecosystem approach.

Many of the small water bodies seem to be overstocked. In a culture-based fishery, an undue increase in stocking density can lead to severe loss of production. It is well known that at higher stocking densities, the fish grow at a slower rate with attendant higher rate of natural mortality. Moderate overstocking results in sub-optimal production due to slow growth and high mortality, but fishery can still operate. On further increase in stocking density, the asymptotic length of the population falls below the gear selection length (if the mesh is selective) and the fishery fails to remove biomass from the population. If stocking continues, the water body is literally choked with stunted population without any production.

Available models have clearly confirmed that production is a function of fishing mortality and stocking density. If some standard variables on population parameters, such as the density- dependent growth, size- dependent mortality and weight-length relationship are known, the optimum stocking density and the fishing mortality can be arrived at. Thus, a desired balance between stocking rate, population density and growth is to be maintained with enough flexibility so as to swing it to suit the changes in environmental factors. Such a plan must determine tentative stocking rates and if required thinning of population.

It has also been pointed out that the highest production is achieved if fish are produced at the minimum marketable size. Thus, it becomes very important to determine the minimum size at which the fish are preferred for domestic consumption or can be marketed. The mesh size regulations and gear selection have to be guided by this parameter. The fishing pressure assessed on the basis of size groups in the population is a useful guide in determining the quantum of fishing effort. This tool has been effectively used in many countries to make necessary adjustments in fishing effort. In reservoirs, the population of some species consists of more than one age group and the older individuals dominate the population in terms of biomass, clearly indicating low fishing pressure. This situation calls for an increase in fishing effort.

Similar models to suit Indian conditions need to be derived from field data. Adoption of rational stocking rates, guided by models, will go a long way in improving the fish yield from small reservoirs.



7.0 Enhancement other than culture-based fisheries

Although culture-based fisheries is considered as the most common form of fisheries enhancement, scope exists for other forms of enhancement such as 'species enhancement', 'environmental enhancement', 'enhancement through new production systems' and 'integrated production systems'.

7.1 Species enhancement and exotics

Decline of indigenous fish stocks due to habitat loss, especially that caused by dam construction is a universal phenomenon. The extent of such fish species loss is not assessed to any reliable degree in many countries. In India, all the major river basins have been affected. Planting of economically important, fast-growing fish from outside with a view to colonising all the diverse niches of the biotope for harvesting maximum sustainable crop from them is species enhancement.

In other words, when a new species is inducted into the system, it is called species enhancement and the species in question could be exotic or indigenous. In case the fish is inducted to a place outside its normal range of distribution, the species is called 'exotic' and the act is called 'introduction'. Species enhancement in small reservoirs can be done either through inducting indigenous species or introduction of exotics; the latter is subject to the prevailing rules and regulations of the government (please see Box on page 38).

7.2 Environmental enhancement

Improving the nutrient status of water by selective input of fertilizers is a common management tool adopted in intensive aquaculture. However, a careful consideration of the possible impact on the environment is needed before this option is resorted to in reservoirs. It is generally believed that most of the lakes and reservoirs may have sufficient nutrient inputs and any excessive nutrient loading can lead to pollution. However, scientific knowledge to guide the safe application of this type of enhancement and the methods to reverse the environmental impacts, if any, is still inadequate. On account of these, this management tool is not commonly applied in India. China is known to have used this practice in a big way to augment production from small reservoirs. Cuba, taking a cue from China has tried manuring of small reservoirs using both organic and inorganic fertilizers. Thailand has also adopted this practice in a selective manner (Sugunan, 1997).

Fertility typically refers to the quantity of nutrients available and higher fertility is usually equated with higher productivity. Primary productivity is the rate at which new organic matter is added through photosynthesis. In most small impoundments, photosynthesis is commonly limited by nutrients, so the greater the fertility, the higher the primary productivity. There is also a positive correlation between primary productivity and fish production.

Box 3: Introduction of exotic fish species in India

In India, fish transferred on trans-basin basis within the geographic boundaries of the country is not considered as exotic and there are no restrictions on such transfers. Thus, Indian major carps (IMC) such as catla is not regarded as exotic to Cauvery or such other peninsular rivers. This is despite the fact that the species is outside its normal range of distribution and peninsular rivers have habitats, distinctly different from that of Ganga and Brahmaputra river systems. The small west-flowing drainages of the Western Ghats, the two large west flowing rivers, Narmada and Tapti, and a number of east flowing rivers of peninsular India, have ichthyofauna different from the Ganga and Brahmaputra river systems. Catla, rohu and mrigal have been stocked in the peninsular reservoirs for many decades now, with varying results. In some of the reservoirs in Southern India, they have established breeding populations. The hallmark of these introductions is the heavy dependence on IMCs.

The country's policy on stocking reservoirs, though not very explicit, disallows the introduction of exotic species into the reservoirs. Despite this, several exotic fish species have found their way into Indian reservoirs and some of them have established as breeding populations, as the case of silver carp in Gobindsagar reservoir in Himachal Pradesh. Common carp is very popular in reservoirs of the northeast where it enjoys a favourable microclimate and a good market. Silver carp, grass carp and tilapia are not normally encouraged to be stocked in Indian reservoirs, though they are stocked regularly in a few small reservoirs of Tamil Nadu and the northeast. Recently, the more dangerous African catfish is being reported from more and more reservoirs in the country causing concern.

There is a case for examining the virtue of selective introduction of some exotic fish species in small reservoirs, which have no connections with the rivers, or those, which dry up completely in summer months. However, such introductions should be made only after proper policy decisions are taken at the national level.

To a large extent, impoundment fertility is determined by the fertility of the locale. Nutrient- rich sites have more fertile waters. The least available nutrient limits productivity. When increased quantities of this nutrient are present, primary production increases until another less abundant nutrient becomes limiting. Phosphorus is frequently the first limiting factor in freshwater impoundments. Fertility may also be limited by nitrogen, carbon, sulfur or other nutrients.

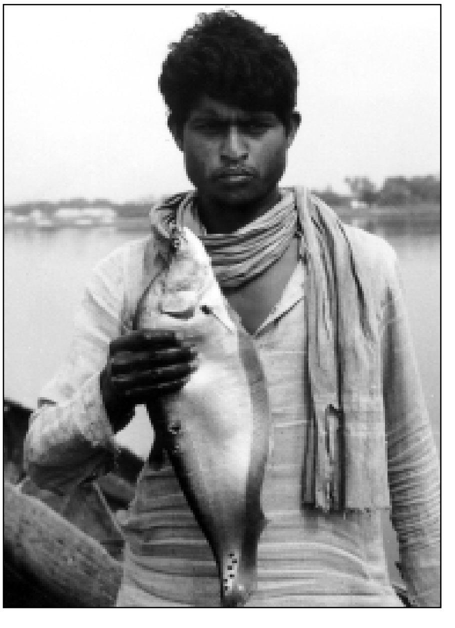
Fertilizers are less effective in soft water with total alkalinity < 20 mg/l. Soft waters have inadequate carbon (usually in the form of carbon dioxide and bicarbonate) for good phytoplankton production. Hence productivity can often be enhanced by applying lime to low alkalinity- impounded waters. The application of lime equivalent to 2 000 to 6 000 kg/ha calcium carbonate is generally sufficient to maintain total alkalinity above 20 mg/l.

Fertilization of reservoirs as a means to increase water productivity by abetting plankton growth has not received much attention in India. Multiple use of the water body and the resultant conflict of interests among the various water users are the main factors that prevent the use of this management option. Surprisingly, fertilization has not been resorted to even in reservoirs, which are not used for drinking water and other purposes. Documentation on fertilization of reservoirs in India is scarce. Sreenivasan and Pillai (1979) attempted to improve the plankton productivity of Vidur reservoir by the application of super phosphate with highly encouraging results. On closure of the canal sluice, 500 kg super phosphate with P_2O_5 content of 16 to 20 percent was applied in the reservoir when the water spread was 50 ha with a mean depth of 1.67 m. As an immediate result of fertilization, the phosphate content of water increased from nil to 1.8 mg/l and that of soil from 0.242 to 0.328 percent. Similar improvements in organic carbon and Kjeldal nitrogen have been reported from soil and water phases on account of fertilization. Experiments were also conducted with urea in the same reservoir.

Eutrophication is a significant problem in both lakes and reservoirs. Wherever the rates of synthesis and input of organic matter exceed the rates of recycling and output, an accumulation of matter within the aquatic system occurs leading to its eventual extinction. Although fluctuating from season to season, such allochthonous energy accumulates in the reservoir system accelerating eutrophication or else entering the food chain in significant quantities.

Application of lime was tried in some upland natural lakes for amelioration of excessive CO_2 and acidity at the bottom (Sreenivasan, 1971). This measure, together with the application of superphosphate in Yercaud lake in Tamil Nadu, raised the pH of water from 6.2 to 7.3 and decreased the CO_2 in bottom water from 38 to 6.5 mg/l. There was a corresponding increase in species number and biomass of plankton. Fertilization in Vidur reservoir resulted in a marked increase in benthic and plankton communities and doubling of the primary production rate. After two successive applications of fertilizers, significant limnological changes took place including the presence of free carbon dioxide and decrease in pH and dissolved oxygen at the bottom layer of water. The methyl orange alkalinity increased from 44 to 108 mg/l from the surface to bottom, indicating high organic productivity. Phosphate fertilization triggered the tropholytic activities mineralising the organic matter and producing carbon dioxide. As a direct benefit from fertilization, a 50 percent increase in fish production, along with three-fold increase in the size (average weight of catla, rohu, mrigal, *Labeo fimbriatus and L. calbasu*) was achieved.

Artificial eutrophication as a decisive management option was tried in India for the first time in Kyrdemkulal (80 ha) and Nongmahir (70 ha) reservoirs of the northeast (Sugunan and Yadava, 1991 a, b) by applying poultry manure (10 t/ha), urea (40 kg/ha) and single superphosphate (20 kg/ha).

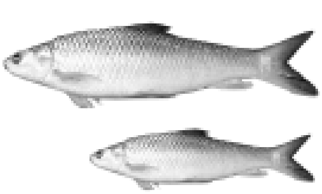


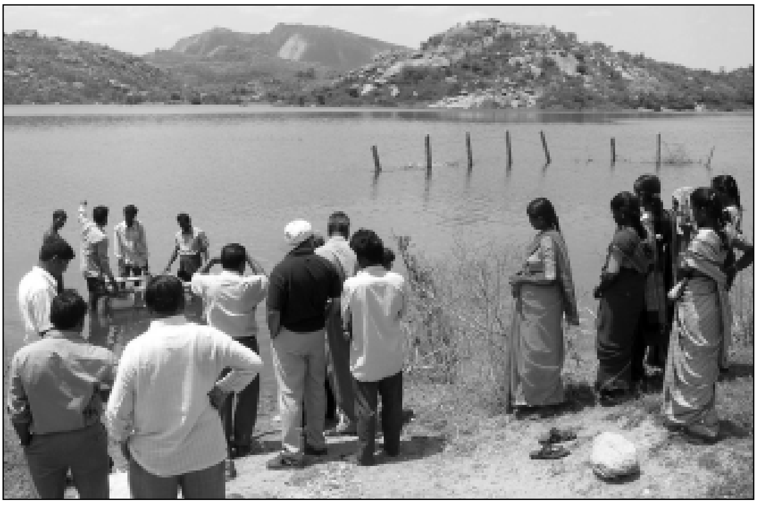
Fertilization can play a key role in many small reservoirs of India, which require correction of oligotrophic tendencies. A number of reservoirs in Madhya Pradesh, the northeast and the Western Ghats receiving drainage from poor catchments show low productivity, necessitating artificial fertilization. Chinese experience in fertilizing small reservoirs for increasing productivity has been reassuring

(Yang *et al.,* 1990). In Shishantou reservoir, a management strategy comprising fertilization by organic and inorganic manures and feeding resulted in phenomenal production hike from 1 500 kg/ha to 6 000 to 7 000 kg/ha during 1985 to 1989. Before fertilization, the plankton biomass in Shishantou was 1.5 mg/l, which was raised to 6.5 mg/l through application of organic fertilizers at the rate of 6 375 t/ha. The plankton biomass, after dropping during the peak precipitation period, picked up to 20.51 mg/l during the post-rainy months, with corresponding increase in fish production.

7.3 Integrated production systems

Small reservoirs are also amenable to integrated aquaculture since the culture-based fishery can be effectively combined with piggery, duckery and poultry rearing. Many of the waste products from these animal husbandry practices act as a fish food or fertilizer enabling higher stocking densities and fish yield. However, this approach has limitations from the aesthetic and hygienic point of view, especially when the reservoir is a source of drinking water supply. Sometimes, the littoral areas of reservoirs are used for agriculture, especially for farming of leguminous crops, which would add to the productivity of the soil. Such increase in fish production and rural earnings can make a significant contribution to the nutritional requirements of the rural community.





8.0 Governance

Technologies for developing reservoir fisheries are relatively simple as described in the foregoing chapters and do not demand high technical skills from managers. Still, the rate of adoption of scientific advice for reservoir fisheries is very low and most of the water bodies in the country are managed arbitrarily leading to low productivity. This is attributed to the lack of enabling governance environment under which these reservoirs operate.

The reservoirs in India are common property resources, generally managed based on community activity. Thus, organization of the community that manages the system plays a key role. Quiet often, on account of inadequate awareness, empowerment and motivation, the community remains incoherent and disorganized and whose members at times act at cross purposes. This not only weakens their ability to negotiate with the other sections of the society, but also makes them easy prey to the unscrupulous elements like money lenders and middlemen. This is the bane of reservoir fisheries throughout the country. In isolated pockets, where the community is well organized and works under good institutional support in the form of effective cooperative societies, Self Help Groups (SHGs), etc, high yield and equitable distribution of profits are reported. Thus, it is not the complexity of the technology but organisation of the community and the governance environment that are responsible for sub-optimal utilization of the resources.

The reservoir fisheries will be successful only when the community that fishes in the water body is under sound governance set up and it owns and manages the fish stock. Co-management, where the representatives of the community and government take part in decision making process, is the most ideal for reservoirs. All stakeholders should take part in the decision making process and the benefits accrued by implementing improved scientific norms should be equitably shared by all stakeholders. In this regard, the State has to play a pivotal role in improving the governance environment of reservoirs by providing an enabling policy support. Ownership of reservoir does not always vest with the Department of Fisheries (DoF) and in many States it has no access and authority to manage the fisheries in reservoirs. In an ideal situation, even if the reservoir is owned by other Departments, at least the fishing activities should be within the purview of the DoF of the respective State Government.

To summarize, the major governance challenges in reservoir fisheries are:

- Lack of appropriate community organizations;
- Lack of institutional arrangement; and
- Lack of enabling policy environment.

Resolving these governance challenges under an enabling policy environment will trigger the process of increasing fish production from small reservoirs in the country.

9.0 Checklist of activities for management of small reservoirs

A systematic and integrated approach towards planning for culture-based fisheries in small reservoirs would be useful adopting the following check-list:

Step I →

- Collection of details of the reservoir
  - ~ Area
  - ~ Depth
  - ~ Ionic status
  - ~ Other parameters related to productivity
  - ~ Facilities for raising stocking material

Step II →

- Review of governance arrangements
- Organization of appropriate community groups and their empowerment.
- Review of marketing and post-harvest arrangements

Step III →

- Estimation of fish production potential
- Selection of species for stocking
- Calculation of stocking rate

Step IV →

- Drawing of stocking-harvesting schedule
- Preparation of project report involving steps I – IV
- Arrangements of funding and other requisites

Step V →

- Raising of stocking material
- Stocking the reservoir
- Monitoring the stock
- Determining fishing units qualitatively and quantitatively
- Harvesting

Step VI →

- Reviewing the experience
- Drawing plans for next year based on the lessons learnt

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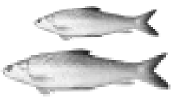
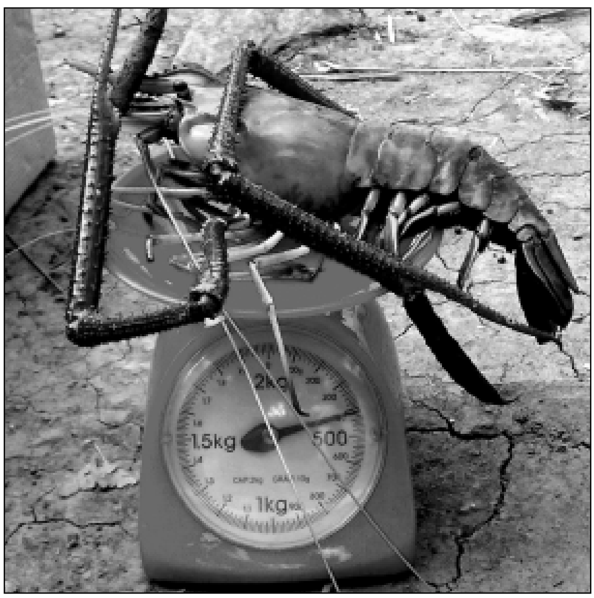
11.0 DOs and DON'Ts

DOs	DON'Ts
Estimate the yield potential for determining the stocking density and fishing effort.	Do not stock without a plan.
In the absence of other criteria use the recommended formula for determining stocking density system for staggered stocking and harvesting, which will lead to better yield.	Do not overstock the reservoir. It will lead to stunted population and drastic fall in yield.
Carefully study the possible stock loss through inlet and outlet channels and account for this while estimating the stocking density.	Do not try to provide wire mesh structures without consulting the dam authorities.
Fix the minimum size at capture and restrict the use of mesh size where staggered harvesting is practiced.	Do not catch the fish at too small or too large size.
Remember that theoretically, stocking at smaller size in large numbers and catching them at the smallest marketable (acceptable) size, will give more yield compared to larger size. However, survival is size- dependent and growth is density-dependent.	Do not grow the fish to larger size than the marketable/acceptable size.
Stock at higher size (100 mm or more) if the predator population is very high.	Do not stock higher sized fingerlings if there is no predator pressure.
Workout optimum fishing effort and limit the number of fishing units.	Do not allow unlimited number of fishing units.
Explore possibilities of stocking locally available indigenous species.	Do not stock exotic fish species without clearance from authorities.
Select fish species for stocking carefully taking into consideration the available fish food resources and the catchability.	Do not stock/overstock fish species only because they are available.
Explore the possibilities of integrating fisheries with animal husbandry practices to make the fisheries more profitable.	Do not practice animal husbandry in reservoirs used for drinking water purposes. Do not fertilize the reservoirs with organic and inorganic fertilizers, unless it is very essential and does not conflict with other uses of water.
Motivate the community to follow mesh size and fishing effort regulations and involve them in management.	Remember that participatory or co-management works better than command and control approach.




1.5kg
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12.0 Glossary

Aquaculture

The farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants with some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated.

Aquatic Organisms

A complex of living organisms and their non-living environment, which are inseparably interrelated and interact upon each other.

Benthos

Animals attached to, crawling on or burrowing into the bottom substrata in a water body with no or limited mobility.

Biological Diversity

The variety and variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Biomass

Also referred to as the standing stock. The total weight of a group (or stock) of living organisms (*e.g.* fish, plankton) or of some defined fraction of it (*e.g.* spawners), in an area, at a particular time.

Brood Stock

Specimen or species, either as eggs, juveniles, or adults, from which a first or subsequent generation may be produced in captivity, whether for growing as aquaculture or for release to the wild for stock enhancement.

Capture-based Aquaculture

Aquaculture system where seed is sourced from natural (wild) collections.

Carrying Capacity

The maximum population of a species that a specific ecosystem can support on a sustainable basis.

Co-management

A governance system in which representatives from the community and government participate in decision making processes.

Common Property Resource

A resource held collectively and managed by a community or a particular group (two or more persons) within a community for the common benefit. Excludes individual rights.

Conservation

Actions, which are directed towards sustaining otherwise decreasing rates of use, towards sustained yield management, or towards increasing a sustained use.

Culture-based Fisheries

Fisheries that depend solely or mostly on stocking (stock and recapture).

Ecological Impact

Effect of human activities and natural events on living organisms and their non-living environment.

Ecosystem

Systems of plants, animals and micro-organisms together with the non-living components of their environment.

Ecosystem-based Management

An approach that takes major ecosystem components and services- both structural and functional- into account in managing fisheries. It values habitat, embraces a multi-species perspective, and is committed to understanding ecosystem processes. Its goal is to rebuild and sustain populations, species, biological communities and ecosystems at high levels of productivity and biological diversity so as not to jeopardise a wide range of goods and services from ecosystems while providing food, revenues and recreation for humans.

Edaphic factors

Water and soil quality parameters that have a bearing on fish productivity.

Enhancement

Qualitative and quantitative improvement in productivity of water bodies through specific management options.

Enhancement through new Culture Systems

Cage culture, pen culture, Fish Aggregating Devices (FADs), etc.

Environment

The combined external conditions affecting the life, development and survival of an organism or an ecosystem.

Environmental Enhancement

Input of nutrients through fertilization to increase plankton for enhanced fish production in reservoirs.

Environmental Impact

Direct effect of human activities and natural events on the components of the environment.

Environmental Impact Assessment

A sequential set of activities designed to identify and predict the impacts of a proposed action on the bio-geophysical environment and on man's health and well being, and to interpret and communicate information about the impacts, including mitigation measures that are likely to eliminate the risks.

Eutrophication

Natural or man-induced process by which a body of water becomes enriched in dissolved mineral nutrients (particularly phosphorus and nitrogen) that stimulates the growth of aquatic plants and enhances organic production of the water body.

Exotic Species

Species not native to a particular area.

Fish Aggregating Devices (FADs)

Artificial substrata provided in natural water bodies allowing fish to take shelter for their easy capture.

Fish Production

Total quantity of fish produced from a water body.

Fish yield

Quantity of fish produced from a unit area and time.

Food Chain

Organisation of plant and animal communities into groups, which are dependent on one another for food. These communities form a trophic chain that transforms energy from one level to the other.

Forage Species

Species used as prey by a predator for its food.

Habitat

The environment in which the fish live, including everything that surrounds and affects its life: *e.g.,* water quality, bottom, vegetation, associated species (including food supplies).

Indigenous species

A species living in its natural range of distribution.

Integrated Production System

Combining fish production with crop and animal husbandry practices to enhance benefits.

Littoral vegetation

Plants, mostly terrestrial adapted to living in submerged conditions at the interface between land and water.

Macrovegetation

Submerged, floating, rooted, emergent or rooted & emergent aquatic plants.

Management Enhancement

Introducing new management options like recreational fishery, etc.

Mortality

Depletion of stock from a population. Depletion due to natural causes is natural mortality and depletion due to fishing is fishing mortality.

Niche

The role and position of a species in an ecosystem.

Oligotrophic

Water bodies deficient in nutrients.

Open Access

A condition of a fishery in which anyone who wishes to fish may do so.

Periphyton

Organisms (mostly microscopic), both plants and animals attached to submerged substrata like stones, pebbles, plant trunks, leaves, etc.

Plankton (Phyto and Zoo)

Floating organisms whose movements are more or less dependent on currents. Plant component is called phytoplankton and the animal component – zooplankton.

Pollutant

Extraneous substances present in concentrations that may harm organisms (humans, plants and animals) or exceed an environmental quality standard. The term is frequently used synonymously with contaminant.

Population

A group of fish of one species which shares common ecological and genetic features. The stocks defined for the purposes of stock assessment and management do not necessarily coincide with self-contained populations.

Precautionary Approach

Set of measures taken to implement the Precautionary Principle. A set of agreed cost-effective measures and actions, including future courses of action, which ensures prudent foresight, reduces or avoids risk to the resource, the environment, and the people, to the extent possible, taking explicitly into account existing uncertainties and the potential consequences of being wrong.

Primary Production

Synthesis of organic carbon by chlorophyll bearing organisms.

Primary Producers

Plankton, periphyton, macro-vegetation and other communities that synthesize carbon.

Recruitment

Adding of individuals into the fish stock through natural breeding and or stocking (artificial recruitment).

Renewable Natural Resource

Natural resources that, after exploitation, can return to their previous stock levels by natural processes of growth or replenishment.

Reservoir morphometry

Measurement of various dimensions of dam and reservoir that has bearing on productivity such as dam height, mean depth of the reservoir, shoreline length of reservoir, etc.

Riparian

Land adjacent to a stream/river.

Runoff

Portion of rainfall, melted snow or irrigation water that flows across the ground's surface and is eventually returned to streams.

Scampi

The freshwater prawn, *Macrobrachium rosenbergii*.

Species enhancement

Inducting new species into the system to enhance productivity.

Species introduction

Inducting species outside its normal range of distribution.

Species Diversity

The variety of species in a community, which can be expressed quantitatively in ways which reflect both the total number of species present and the extent to which the system is dominated by a small number of species.

Stakeholders

Individuals/groups who have an interest or derive benefits from the system.

Stock Enhancement

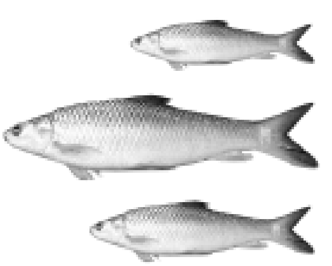
Enhanced capture fisheries. Augmenting stock by building a breeding population.

Sustainable Use

The use of components of biological diversity in a way and at a rate that does not lead to long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

Sustainable Yield

The amount of biomass or the number of units that can be harvested currently in a fishery without compromising the ability of the population/ecosystem to regenerate itself.



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