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A Model Strategic Framework for Prioritization and Development of Inland Water Bodies under Fisheries and Aquaculture

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Abstract

The present article summarizes the available management options and strategies for development of fisheries & aquaculture in inland water bodies. Each section focuses on the key issues or parameters that are crucial from fisheries and/or aquaculture point of view.

Keywords: Inland water bodies; Multiple harvesting; Water residence; Wet land

Introduction

The present article summarizes the available management options and strategies for development of fisheries and aquaculture in inland water bodies like wetlands, reservoirs, lakes and ponds. In order to realise higher production from fisheries sector in coming years both vertical and horizontal expansion of fisheries and aquaculture is required. Vertical expansion refers to the increase in production per unit area whereas horizontal expansion refers to the increase in area of production [1]. Both these expansions require resource specific strategic framework. This article primarily focuses on the theme of horizontal expansion of fisheries and aquaculture activities in inland water bodies by bringing more area under scientific management and exploitation. Each section focuses on the key issues or parameters that are crucial from fisheries and/or aquaculture point of view.

Depth

Depth often determines the water quality and hydro-period in a water body. Simultaneously, it also influences the fisheries and aquaculture activities associated with it. Although the shallow water bodies are prone to partial or complete drying up during summer but they are often found to be convenient for management and harvesting by the fisher folk community. On the other hand, water bodies with medium water depth are capable of remaining water laden even in dry months and also are quite convenient for management or harvesting. Deep water bodies have their own difficulties associated with them especially in terms of ease in management and harvesting [2]. Therefore, a depth wise strategy in managing the inland water bodies will be highly useful as far as the interests of fisher folk community is concerned. Table 1 categorically enlists the assortments against the depth.

Utilization

Traditional perception of fisher folk community often agrees with the fact that the preference or utility of an inland water body for fisheries and aquaculture depends on its water residence period or hydro-period [2]. Therefore a hydro-period based priority for utilization of inland water bodies is worth recommending, which is discussed below.

If the water body retains the average depth in the range of 3-10 m for 7-10 months, it *must be utilized* for fisheries and aquaculture under co-operative management (in Japanese or P3 model), if not already being utilized for the same.

Japanese model of co-operative management is based on the principle of community based approach towards management and utilization of a natural resource with dual objectives of sustainable development of the community through rational exploitation of the resource and conservation of the natural resource through voluntary endeavors. P3 model implies public-private partnership where local government or statutory authority (public component) assigns time bound utilization and exploitation rights of a natural aquatic resource to an entrepreneur or enterprise or group of companies (private component) for their commercial venture and obtains revenue in return.

Non-utilization Issues

Several social, environmental and policy driven issues often create conflicts with the interests of fisher folk community leading to the non utilization of some aquatic resources for fisheries and aquaculture [3]. Table 2 discusses some issue specific fisheries development strategies which can bypass the conflict of interests and enable proper exploitation of the non-utilized aquatic resources.

Type of ownership

Various mode of ownership in inland water bodies have their relative advantages and disadvantages in undertaking these for fisheries and aquaculture. In order to initiate fisheries development in inland water bodies certain ownership specific strategies need to be sketched out beforehand in alignment with the interest of associated stakeholders [4]. Table 3 enlists some available options that might be suitable for adoption under various ownership regimes.

Connectivity status

Connectivity status of inland water bodies is an important parameter that needs prior consideration for successful fisheries and aquaculture planning. As per connectivity, inland water bodies can be categorized as open, semi-open and closed systems. Open systems

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<5 m depth	5-10 m depth	>10 m depth
Suitable for pen culture.	Suitable for cage culture.	Suitable for cage culture.
Culture of mollusks/ bivalves in submerged cages can be promoted.	Stock enrichment (species diversification) of surface/ column occupying fishes (especially SIFs) should beprioritized through periodic stocking or transplanting.	Stock enrichment (species diversification) of surface occupying fishes (especially SIFs) should beprioritized through periodic stocking or transplanting.
Stock enhancement of various SIFs, perches and catfishes through ranching can be explored through repeated staggered stocking or transplanting.	Ranching or enhancement of bottom dwelling fishes should be avoided as they are generally hard to catch and harvest at greater depths will be unpredictable.	

Table 1: Depth-wise fisheries management strategies for inland water bodies.

Issue	Assortment
Multiple ownership	Cooerative management option in Japanese or P3 model can be explored.
Social issue	Incorporation of eco-tourism might ameliorate the issue.
Protected areas	Any human intervention (either capture or culture) should be avoided. Areas like these should be excluded from fisheries/ aquaculture planning. However, periodic ranching of endangered and commercially important fish species in these areas might be considered from conservation point of view.
Weed	A combination of manual, mechanical, chemical and biological methods of weed control over a long period of time (3-5 years) should be employed in a sequentially planned manner to reclaim the water body. If the floating/marginal aquatic weeds or algal scums predominate, impart high confidence on successful reclamation of these water bodies for fisheries purposes. If the emergent aquatic weeds or benthic algal mats predominate, impart medium confidence on successful reclamation of these water bodies for fisheries purposes. If the submerged aquatic weeds predominate, impart low confidence on successful reclamation of these water bodies for fisheries purposes. If the depth is shallow, Stock enhancement/ enrichment of air breathing fishesshould be prioritized in these waters. Stock enhancement/ enrichment of herbivorous cyprinid fishes should be prioritized in these waters.

Table 2: Issue specific fisheries development strategies for non-utilized water bodies.

Ownership	Options
Private	Medium/Long term leasing to cooperative societies can be considered. Leasing to fisherman groups on revenue (yearly/ fishing season) basis. Adoption of P3 (Private-Public Partnership) management can be considered. P3 concept has already been discussed before.
Public	Medium/Long term leasing to cooperative societies can be considered. Leasing to private entrepreneurs on revenue (yearly/ fishing season) basis. Adoption of P3 (Private-Public Partnership) or P4 model (Private-Public-People Partnership) management can be considered. P4 concept is discussed below.
Disputed	Adoption of P4 model (Private-Public-People Partnership) management can be considered. Example (P4 model): - Government will stock the seeds and manage the water body, local fisherman community are given right to fish. The fishermen community sells their harvest to a pre-determined private entrepreneur at a fixed price and quantity. The private entrepreneur does value addition and sells accordingly. Government earns sale-basis revenue from the private entrepreneur. Side by side, the concept of eco-tourism can also be promoted in the area, which will be owned by a group of private companies that must recruit locals for employment. Government can include a fixed service tax in the services given by the private entrepreneurs for earning revenue.

Table 3: Ownership specific fisheries utilization strategies for inland water bodies.

retain continuity with the parent rivers or streams for the whole year. They have continuous exchange of water and fish fauna. Semi open systemsget connected with the parent river or streamonly during the rainy season. They have seasonal exchange of water and fish fauna. Closed systems are completely cut-off from the nearby rivers or streams. They receivewater and fish fauna mostly from their catchment areas following monsoon rains or during high flood. In recent years, embankments constructed for flood control, irrigation purpose and hydro-power generation have convertedmany open systems into closed ones by blocking the riverine connections [3]. Table 4 explores some potential fisheries and aquaculture development strategies for inland water bodies of different connectivity status.

Connectivity status 10 years back

It is optional to enquire about the recent changes in geomorphology of an inland water body that is being targeted for fisheries development especially in terms of its connectivity status through perception based interview of the locals on NOW (present) and BEFORE (past) basis. The rationale of this idea remains in the projection of any adversities, if any, associated with the water body which can be faced or expected by the lessee or stakeholders who are undertaking these for fisheries and aquaculture. Moreover, it will enable proper hedging and situation specific planning of fisheries and aquaculture in such water bodies for short, medium or long term basis.

If NOW=*Closed* or *Semi open* and BEFORE= *Semi open* or *Open*, investigate on the influence of sedimentation, water abstraction, dam construction in the upstream and/or weed proliferation issue. Also take perception on the duration of peak season BEFORE and NOW.

Water residence (hydro-period)

As discussed before, traditional perception of fisher folk community often agrees with the fact that the preference or utility of an inland water body for fisheries and aquaculture depends on its water residence period or hydro-period [2]. Therefore, a hydro-period based priority scale for fisheries development in inland water bodies is worth recommending. A model priority scale is given in Table 5. Such scheme can be uniformly implemented on a nationwide scale and used to create GIS based maps or e-atlas of inland water resources in relation to fisheries and aquaculture

Other uses of water

Multiple uses of water often create social conflicts and create

Connectivity	Assortment	Checkpoints
Open	Unsuitable for stock enhancement and/or stock enrichment, as the stocked fishes may escape or disperse widely. Suitable for enclosure based culture of fishes at higher stocking densities due to the flowing/semi-flowing nature of water. SSMH* (single stocking multiple harvesting) or MSMH** (multiple stocking multiple harvesting) technique recommended. Fishing should be banned during April to June for allowing fish to breed and establish its population.	Enquire about the lean and peak season of catch (in terms of value). Correlate it with temperature and precipitation pattern (meteorological parameters) and generate a catch prediction system.
Closed	Suitable for stock enhancement and/or stock enrichment. Enclosures installed in such water bodies may be stocked with fish at higher stocking densities initially but due to the stagnated nature of water, thinning of stock is essential. SSMH technique recommended.	Enquire about the lean season of catch (in terms of value) and impose voluntary ban on fishing activities for population re-establishment.
Semi-open	Unsuitable for stock enhancement and/or stock enrichment, as the stocked fishes may escape or disperse widely when the connection opens. Fishing should be banned during April to June for allowing fish to breed and establish its population. Trapping and culture method can be employed. When the connection opens, natural seeds are collected/ trapped and contained inside enclosures for 4-6 months before they are harvested. Intense fishing should be done just before the connection opens.	Enquire about the opening and closing of the water body. Correlate it with the value of catch during each phase. If the number differs, develop a co-operative which should be divided into two groups - Fishermen and Fish farmers. Follow the plan given below:- Capture phase: When the water body opens, exclusive harvest from capture fisheries through fishermen will generate revenue. Capture and Stock phase: As the water body starts to close (but not closes completely), relaying of high value fish seeds from the water into the enclosures maintained by fish farmers is done in a staggered manner at high densities. Simultaneously, capture fisheries continue. Culture phase: As the water body closes, the stocked seeds are either raised within enclosures and harvested by multiple harvesting (stock thinning)process or released back into the water body for stock enhancement/enrichment to sustain high value catch even after the water body closes. Both can also be done simultaneously.
*SSMH: Single Stocking Multiple Harvesting. Fishes are stocked once in high densities and harvested at periodic intervals, based on size [5]. **MSMH: Multiple Stocking Multiple Harvesting. Fishes are stocked multiple times based on seed availability and harvested periodically based on size. Harvested stocks are replenished again through stocking of new batches. The cycle repeats several times a year [5].		

Table 4: Connectivity status wise fisheries and aquaculture development strategies for inland water bodies.

Priority for fisheries development	Water residence period (number of months)
High	9-12
Medium	6-8
Low	4-5
No priority	<3

Table 5: Hydro-period based priority scale for fisheries development.

Other uses	Assortments
Irrigation	Classify the water body under 'high vulnerability' to water stress, sedimentation and social conflict that will play key roles in impeding fisheries development in these water bodies. Solution:Partitioning of resource use needs to be done.
Jute retting	Classify the water body under 'high vulnerability' to water acidification (drop in pH), accumulation of unionized ammonia and hydrogen sulfide that will render the water unfit for fishes. Solution: Waters planned for fisheries development should be prohibited for jute retting.
Drinking water	No problem except the fact that there should be a ceiling on the amount of water being abstracted for the purpose.
Industry	Classify the water body under 'high vulnerability' to point sources of pollution. Also impart 'medium confidence' on the marketability of the fish harvest from these waters if consumer preference and impacts on human health is considered. Solution: State fisheries department must approve fisheries development after reviewing effluent reports and no objection certificate (NOC) issued from national environmental agenciesto the industries, around the concerned water bodies.

Table 6: Fisheries and aquaculture suitability of inland water bodies having some other uses.

reluctance among fisheries stakeholders in adopting such water bodies for commercial fisheries and aquaculture venture [4]. To avoid such conflicts of interest and reluctance in adoption, the suitability of particular water body for fisheries and aquaculture needs to be assessed beforehand. Table 6 discusses the fisheries and aquaculture suitability of inland water bodies having some other uses.

Dominant catch composition

Before considering any inland water body for commercial utilization through fisheries and aquaculture, it is highly recommended to assess its dominant residential fish stock composition by either perception based study of local fisher folk community or conducting an experimental fishing. The underlying rationale of this particular strategy lies in prioritizing a particular water body for successful commercial exploitation and project realistic expectations from that particular water resource. Table 7 represents a model prioritization scheme of inland water bodies based on dominant fish group existing therein.

Scientific management adopted

In case an inland water body is already under ownership it is essential to enquire whether any scientific management is being implemented in its fisheries and aquaculture activities. This will aid in marking those water bodies which require immediate attention and water bodies which are already being scientifically utilized.

If scientific management is being applied, classify the water bodies as '*utilized*'. If scientific management is absent, classify the water bodies as '*potential*'.

Category	Assortment
Major and Minor Carps	Status: High priority for commercial utilization. Commercial utilization of water body is possible and further commercialization through P3 mode and scientific management can be remunerative in the long run.
Exotics (Chinese carps, tilapia, etc.)	Status: High priority for commercial utilization. Commercial utilization of water body is possible and further commercialization through stock enhancement of indigenous carps (to rule out any possibilities of invasion and establishment of exotic fishes at the expense of indigenous fishes) should be done.
Catfishes and Murrels	Status: Medium priority for commercial utilization. Although, catfishes and murrels fetch high market price. The harvest of catfishes and/or murrels is highly unpredictable due to their bottom dwelling and escaping nature. The commercial utilization of these water bodies can only be a success if selective harvesting techniques for catfishes/murrels are employed and simultaneously other groups of fishes are abundantly available.
Small Indigenous Fishes (SIFs)	Status: Low Priority for commercial utilization and high priority for conservation SIFs are indigenous small sized miscellaneous fishes of lesser commercial importance. They are a rich source of essential amino acids and micronutrients but still considered as poor man's fish. They are mostly consumed by the fishermen community themselves. They have region specific preferences and their prices are subject to high fluctuations, both spatially (place to place) and temporally (time to time) which restricts their commercial utilization. Their declining biodiversity and abundances have been reported from many places [3]. To warrant the protein security for poor households, their conservation is necessary.

Table 7: Prioritization scheme of inland water bodies based on dominant fish group existing therein.

S.No.	Scientific management options
1.	Estimate the potential yield of the water body through morpho-edaphic index [1].
2.	Observation of closed season for fishing activities (Preferably fromApril to June) for population re-establishment as the breeding season of majority fishes initiates during this period.
3.	Estimate stocking rate through Welcomme's formula [1].
4.	Mesh size regulation of gill netsand trawl nets for sparing juveniles.
5.	Ban on non-selective gears (used for catching SIFs) between February and March for allowing SIFs to breed.
6.	Enclosure based culture (Pens and cages) under SSMH/MSMH technique. For more details, refer Table 4.
7.	Implementation of culture based fisheries (for closed/ seasonal water bodies having <1000 ha area).
8.	Environment management (weed control, adaptation or mitigation measures against sedimentation, check on amount of water abstraction, control on catchment sources of pollution).
9.	Capture fisheries in the model of *Jano Fishery* followed in Chilika lake, Odisha [1].
10.	Relaying/ Ranching of high value fishes from open phase to closed phase of water body to sustain availability. For more details, refer Table 4.
11.	Planned staggered stocking with multiple size fish seeds after closing of water body and staggered harvesting before opening of water body (for semi open water bodies only).
12.	Trap and hold method of culture based fisheries as practiced in Italy (*valli culture*) and Arachnon in France [1].

Table 8: Scientific fisheries and aquaculture management packages for inland water bodies.

For '*potential*' water bodies, settle the ownership issues of the water body through auctioning mid-term or long-term lease and bring themunder P3/P4/ self help group/youth club/Co-operative mode of management on priority basis.

Table 8 enlists some useful scientific fisheries and aquaculture management packages for inland water bodies. After settlement of proprietorship, it is recommended to implement the convenient scientific management option(s) among the following.

Record of fish production

In case an inland water body is already being utilized for fisheries and aquaculture, enquire whether a record of production statistics is being maintained by the concerned management body or owner. If no such record keeping of fish production exists, make the record keeping mandatory and pursue the concerned owner for the same on following grounds: -

Time series data will reveal any changes in yield, value of catch, composition of catch, peak season, lean season, water recharge time, water residence duration and per capita income of co-operative/self help groups/group/company members.

Help in apt response/control during any adverse or disruptive change/trend, through management interventions.

Presence of production data will help in prioritizing a water body for intensified fisheries development and strategizing resource specific management plans.

Annual fish production

In the presence of fisheries and aquaculture production statistics, it is possible to classify an inland water body as productive or under-productive by comparing the resource specific production figure with its national average. Such classification scheme can be uniformly implemented on a nationwide scale and used to create GIS based maps or e-atlas of inland water resources in relation to fisheries and aquaculture. Table 9 represents a model classification scheme for various inland water bodies based on fisheries production. Here the benchmark production refers to the existing national average of fisheries production from a particular category of inland water body [1]. The water body whose average annual production is greater than its benchmark production is classified as 'productive' and the opposite is classified as 'under-productive'. The water bodies classified as 'under-productive' are separately marked and prioritized for intensification of fisheries and aquaculture activities.

Comparison of production (trend of production)

Before launching any fisheries development programme, it may be coherent to study the catch or production trend of a few inland water bodies in the area which are already being commercially utilized for fisheries and/or aquaculture under any ownership regimeatleast for last ten years. The study involves simple comparison of present fisheries production with the past production figures, in case the data are available or through perception based study of associated stakeholders, in case of data deficiency. The objective of this strategy is to devise a

resource specific, region specific and qualitative SWOT (Strength-Weakness-Opportunity-Technology) analysis for the projected venture of fisheries and aquaculture activities in inland water bodies. Table 10 enlists some situation wise focal themes of enquiry which is to be covered in the questionnaire drafted for such study.

Classification for degree of management

Voluntary release of fish seeds (eggs, spawn, fry, fingerlings, juveniles or adults) into a water body is referred as stocking. It is considered as one of the foremost management intervention in the scientific fisheries and aquaculture package [5]. Based on the presence and/or absence of stocking along with its associated management options, a model classification scheme is proposed for assigning degree of management in inland water bodies under any ownership regime (Table 10). Such classification scheme can be uniformly implemented on a nationwide scale and used to create GIS based maps or e-atlas of inland water resources in relation to fisheries and aquaculture

Presence of enclosure culture

The mere presence of capture fisheries in an inland water body excluding culture fisheries is ecologically unsustainable and economically less viable [1]. Therefore in order to utilize an inland water body for medium or long term commercial exploitation, it is essential to integrate provisions of culture fishery on high priority. In extensive or large water bodies enclosure based culture serves as the best medium for aquaculture [3].

If no such provision of aquaculture is present in an already utilized inland water body, then recommend enclosure based culture technologies therein based on the aforementioned criterions (Tables 1- 6).

Whether aware of technologies

Determination of the level of awareness existing among the fisher folk community regarding various facets of fisheries and aquaculture is necessary for ensuring the success of a fisheries development programme in any inland water body (Table 11). It also plays a major decisive role in the viable commercial reclamation of any under-utilized or non-utilized water body [2].

For this purpose, a simple perception based study needs to be conducted in the area whose action plan is discussed below.

Firstly enquire whether they (members of fisher folk community) are aware of certain technologies associated with fisheries and/or aquaculture.

If 'Yes', classify the fisher folk community as '*aware*'. Then investigate on the extent of adoption and ease of applicability of technologies. Also obtain feedback on priority basis whether any lacunae, technology gap or knowledge gap exists.

Resource	**Benchmark** *based on national average* [1].	**Classification scheme**
Reservoir	50 kg/ha/year (<1000 ha) 12 kg/ha/year (1000-5000 ha) 11 kg/ha/year (>5000 ha)	Greater than benchmark = Productive Less than benchmark = Under-productive*
Wetland	100-150 kg/ha/year	-Do-
Pond	2500 kg/ha/year	-Do-
Lake	Data not available	Could not be generated
*Intensification of fisheries and aquaculture activities is recommended for 'Under-productive' water bodies with high/medium/low priority based on Table 5.		

Table 9: Classification scheme forinland water bodies based on fisheries production.

Situation (trend of production)	**Focal themes of enquiry**
Production increased (Now>Before)	1. Implementation of culture based fisheries (includes stock enhancement, species enrichment, environment enhancement/ management, technology diversification). 2. Better record keeping. 3. Improved capture efficiency through mechanized crafts and improved gears. 4. Better ownership regimes under co-operative/ community/ group management and checking of indiscriminate fishing/ overfishing. 5. Ranching or relaying of high valued fish species through induced breeding and seed production or capture and restocking.
Production decreased (Now<Before)	1. Occurrence of growth overfishing. 2. Occurrence of recruitment overfishing. 3. Habitat destruction (breeding and/or nursery grounds) through sedimentation and weed proliferation. 4. Water stress (reduction in hydro-period and/or volume). 5. Point and non-point sources of pollution. 6. Invasion of predatory exotic/non-native species of fish, parasites or pathogens. 7. Occurrence of any fish epidemics (diseases).

Table 10: Situation wise focal themes of enquiry for a model SWOT study of inland water bodies with reference to fisheries and aquaculture.

S. No.	**Criteria**	**Degree of management**
1.	Stocking + No Feeding	Extensively managed
2.	Stocking + Fertilization and/or Supplementary feeding	Semi-intensively managed
3.	Stocking + No feeding + Fertilization	
4.	Stocking + No feeding + Mesh size regulation and/or Catch limit + Observance of closed season and/or Declaration of closed area	Responsibly managed
5.	No stocking + No feeding + Mesh size regulation and/or Catch limit + Observance of closed season and/or Declaration of closed area	Semi-responsibly managed
6.	No stocking + No feeding + No regulations	Unmanaged

Table 11: Classification scheme for assigning degree of management in inland water bodies under ownership regimes.

If 'No', classify the fisher folk community as '*unaware*' and assign 'high priority' to the concerned community for technology or knowledge dissemination through fisheries extension activities.

Note: The author takes full responsibility in declaring that the present article is intellectual creation of the author himself and is not part of any ongoing/completed project and/or research work of ICAR-CIFRI, Barrackpore.

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