Ecological and Institutional Analysis of Inland Fisheries Resource Management: Productivity in the Case of Tawa Reservoir, India

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ABSTRACT

Fishing in inland water bodies such as flood plain lakes, river, estuaries and reservoirs, has an important role for rural people. Fish is an important source of protein diet of many households and generate significant income as well as provide employment opportunities. 70 percent of the 0.71 million active fisher folks in India are employed in the inland fisheries and India has a total of 19,370 reservoir units covering an area of 31, 53,366 hectares, hence creates a lot of opportunities for economic development of the rural people. Reservoir fisheries are classic case of Common Pool Resources (CPRS) and hence require comprehensive institutional arrangement that can ensure productivity of the fish resources without compromising with the ecological needs. Therefore, through the case of Tawa reservoir, we are trying to understand the fisheries resource and the production scenario. Tawa reservoir has undergone operation through different management regime, and hence, provides an opportunity to comprehend the performance of these regimes and their implications on fisheries resources. In this paper, our attempt is therefore, to understand the dynamics of the fisheries resource of Tawa reservoir. With the limited available data, we analyse the catch and stocking relationship, predator-prey relationship and also to identify the determinants that influence the productivity of the Tawa reservoir. Based on the time-series data available a model was developed to determine the production possibility of the fish resource in Tawa. Our finding suggests that among different regimes existed in Tawa fisheries management, the cooperative form under Tawa Matsya Sangha (TMS)'s performance is better.

Key Words: **Reservoir Fisheries, Common Pool Resources, Production Possibility, Institutions, Tawa, India**

JEL Classifications: C32, O13, P51, Q22

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Ecological and Institutional Analysis of Inland Fisheries Resource Management: Productivity in the Case of Tawa Reservoir, India

Introduction

Fishing in inland water bodies such as flood plain lakes, river, estuaries and reservoirs, is an important activity of rural people. Fish is an important source of protein diet of many households and generate significant income as well as provide employment opportunities. Nearly 70 percent of the 0.71 million active fisher folks in India are employed in the inland fisheries (Ninan and Kumar 2002). According to Sagunan (1995) India has a total of 19,370 reservoir units covering an area of 31, 53,366 hectares. Reservoir is defined as human-made impoundment with a large body of standing water (Ninan and Kumar 2002). They are generally created by impoundment of a river or stream with irrigation, power generation, flood control or water supply as primary objective. Reservoir fisheries considered generally as a subsidiary activity. Since fishing in the reservoirs is a labor-intensive activity, it acts as a major important source of employment for people around the reservoirs, especially the displaced one during the construction of dam.

Inland Fisheries is a complex subject. This paper in the process of unfolding the complexities attempts to understand the dynamics of the fisheries resource of Tawa reservoir from stocking and catch point of view. With the limited data, an attempt is made to identify the Predator-prey relationship and also the determinants that influence the productivity of the Tawa reservoir. Based on the available data a model is developed to determine the technical efficiency and production possibility of the fish resource.

Location and brief History of Tawa reservoir

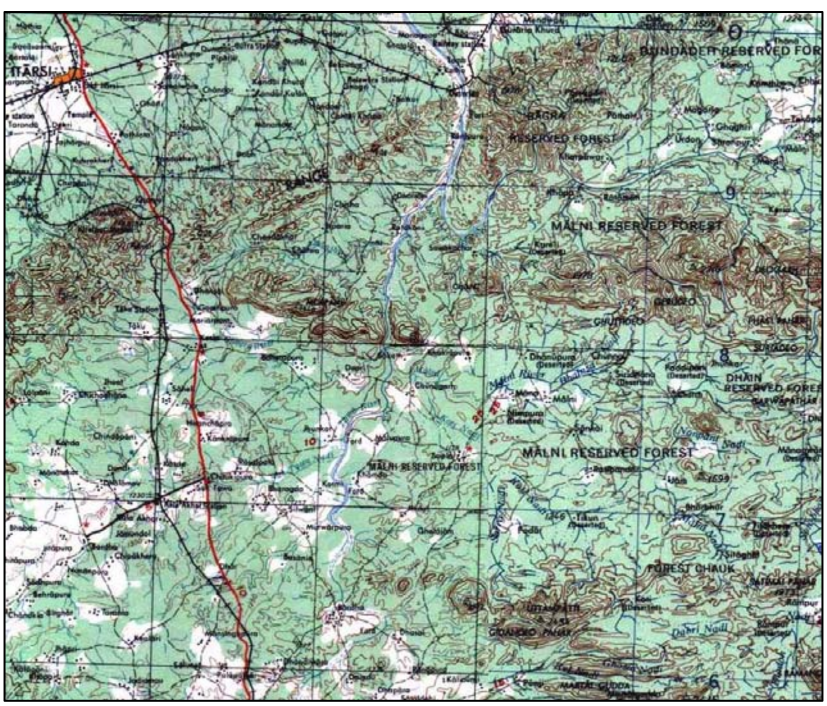
The Tawa is a multipurpose human-made reservoir situated on the river Tawa in Hosangabad district of Madhya Pradesh. Tawa River, a left bank tributary originates form Mhadeo hills in Chindwara district, flows through Betul and joins Narmada in Hosangabad district. It is the longest Tributary of Narmada (172 Km) on the left bank (Chatterjee, Undated). Apart form Tawa dam there is another dam; Sarni (1012 ha.) that has been constructed on the upper reaches of this tributary.

At Tawa, Denva River joins Tawa River 823m upstream of Tawa dam site. This reservoir is located near Ranipur village, 35 Km form Itarsi railway Junction (figure: 1). The dam is positioned at latitude of $22^{0}30'40''$ N and a Longitude of $77^{0}56'30''$ E. The catchment area of the project is 5982.9 Km^2.

The construction of Tawa dam was started in 1956 and completed in 1974, but the reservoir was filled to its full capacity, only in 1979. Earlier it was primarily conceived as an irrigation project. Later however, dam is also used for generation of minor power and for fishing activity (Pandey and Mukhopandhyay, undated). The total submerged area of the dam is 20,050 ha. However, on an average reservoir area is 12,145 ha. The reservoir falls under the administration area of Hosangabad district, within the Kesla and Sohagpur development blocks (Talukas).

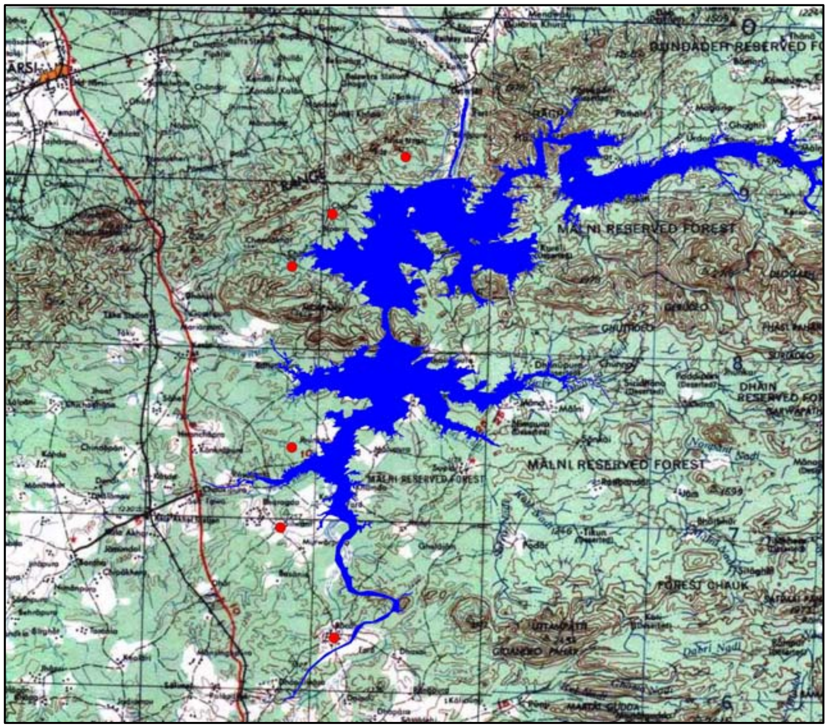
The existing bed of Tawa Reservoir before the construction of the Tawa Dam housed about 44 villages, out of which 27 were forest villages and remaining 17 revenue villages (figure 1 Pre-dam scenario).

Figure 1 Pre Tawa Reservoir 1956



Source: Army map service (L.D.) U.S

Figure 2 Post Tawa Reservoir as on1999



Source: Terra server satellite image 1999 superimposed on Army map service (L.D.) U.S 1956

The construction of the Tawa dam led to submergence of 20055 ha. of land, which included 15056 ha. of forest resource area, 1081 ha. of farmland, 4353 ha. was grass and small forest area and 151 ha. was inhabited 44 villages as mentioned above (Ninan and Kumar 2002)[1]. The displaced forest villagers either moved to higher elevated areas or shifted to the adjoining villages in and around the reservoir[2]. Their inhabitation is still in threat, since, they don't have legal rights on lands. Resettlement package like, compensation for the lost land due to submergence, or providing area to build their houses, was largely restricted to the revenue villages. In general, the displaced population consists of mostly *Gonds* and *Korus*, the predominant indigenous communities of the region. This people were mainly dependent on the agriculture and forest for their livelihood. Due to the dam submergence they lost a major part

[1] For a Pre and Post Tawa Dam construction scenario see figure: 1 and figure: 2.

[2] The displaced villages are not marked in the Pre Tawa scenario since the base map used is dated to 1956

of their income sources and settled along the reservoir bank. These areas were part of the reserved forest and hence made it difficult for them to get a piece of land for agriculture.

The present population around the reservoir largely consists of tribals (*Gonads and Korus*). Apart from tribals there are traditional fisherman the *Kahars* and *Dimmers* and various other people belonging to different communities who came to work as labourer during the construction of the dam, and later on settled at Tawa. At present, the villages which are around the reservoir, are involved mainly in fishing activities. The people who own land practices agriculture along with fishing, while some people who don't own land practice agriculture in the draw down area. The tribals apart from fishing and agriculture are also involved in collection of non-timber forest produce, but are presently facing resistant form the forest authority.

Fisheries Resource of Tawa

Fishing is presently a major source of income for the many displaced people of Tawa reservoir. This fish resource can be further divided into type of fish species existing in the reservoir. The original fishes found in the Tawa rivers were mainly of C*. Mrigal, L. Calbasu, Badas* (local name), other minors and predator catfishes like *A. Seenghala, Samal* and *Padhin* (local names) (Saghunan 1995). When the reservoir was constructed and fishing activity was taken up, the fisheries department introduced two exotic[3] species *C. Catla and L. Rohu*, which were major commercial fishes. According to local fisher folk a few other fish species like the *Glass Carp* and *Silver Carp* came into the reservoir due to flooding of breeding ponds in Sahapur area, upstream of the Tawa River.

Presently, species like *C. Catla, L. Rohu, C. Mrigal, L. Calbasu, Badas, A. Seenghala, Samal, Padhin Glass Carp and Silver Carp* inhabit Tawa reservoir. Out of these *Catla* and *Mrigal* are commercial fishes that dominate the catch. Apart form this the local Majors, *A. Seenghala*, which fetches a higher price in the market, also has substantial catch (table: 1).[4] The other fishes like *Silver Carp* and *Glass Carp* are very rarely sited or caught.

[3] Species that are introduced or non-native: foreign.
[4] All the Predators found in the Tawa reservoir fetches higher prices in the market, compared to the introduced species in the reservoir.

Table 1 Fish species reflected in catch (Kg) In Tawa reservoir in last 8 years

YEARS	Catla	Rohu	Mrigal	Badas	Kalbasu	Local minor	Singhad	Samal	Padhin
1996-97	47932	4286	21735	1287	2447	5225	8636	1941	260
1997-98	163282	6395	30503	2622	3736	19224	12538	7149	291
1998-99	232341	8839	43944	3046	6919	22761	14366	9276	2883
1999-00	268005	5504	36265	2418	4012	44830	19093	11366	1660
2000-01	197144	4854	39722	1824	3025	40975	22896	13120	3600
2001-02	165399	5447	33922	1860	3633	35762	15009	6954	1064
2002-03	74844	7699	34926	2460	5365	47360	16824	8934	3719
2003-04	65553	7731	31583	2455	5763	50890	19425	10160	2262

Source-Tawa Matsya Sangh Annual Reports

In order to sustain fish as a renewable resource, the harvest rate of fish should at the most be equal to its growth rate. In recent times there are many cases around the globe where the harvesting rate is more than the growth rate and this has led to depletion or extinction of many species. Harvesting technique and types of gear used are also important factors in case of fisheries catch. If the gears used for harvesting target even the juvenile fishes, than there is a possibility of high mortality rate of fingerlings [5] and hence affect the harvest. Apart from this, harvesting fish in breeding season also affects the growth rate of the fish and hence the renewing ability of the fish resources.

Each individual species is unique in terms of growth rate, mortality rate, food habits, breeding seasons and maturity period. In order to evaluate fisheries resource one has to know the biological characteristic of fish and its interaction with the co-habitats. Usually, riverine fisheries are based on capture activities where regeneration of fish is left to the nature. Whereas, in case of reservoirs like Tawa, are managed on stocking-cum-capture basis, where apart from natural regeneration, fishes are stocked from external sources. There are three major species *C. Catla, L. Rohu, C. Mrigal*, which are stocked in the Tawa reservoir[6]. Apart from this, it is also important to understand the stocking dynamics in Tawa reservoir and the implication of predator-prey relationship. The catch and stocking ratio will give a better idea of the mortality rate of stocking and hence would help to derive the relation of catch to stocking.

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[5] Stock of fish is the number of fish or the aggregate weight of the fish population measured at a point of time. (Hartwick and Olewiler, 1998)

[6] There are intensive studies done on these three species around reservoirs in India that can be found in various websites.

Stocking of Fingerlings in Tawa Reservoir

Above mentioned three species namely, *Catla, Rohu* and *Mrigal* are stocked in Tawa reservoir. The present regime in Tawa is stocking fingerlings at an average rate 45.53 percent of Catla, 28.83 percent of Rohu and about 25.64 percent of Mrigal. In other terms, it amounts to an average of 28-lakh fingerlings stocking/year, and an average of 236 fingerlings per hector (table no: 2).

Table 2 Stocking of Fingerlings in Tawa Reservoir

Year	Catla %	Rohu %	Mrigal %	Total (n=100%)	Stocking/ Hactare
1997-98	52.75	18.4	28.85	2,613,865	215
1998-99	42.9	28.86	28.24	2,790,460	230
1999-00	45.73	33.04	21.23	2,947,800	242
2000-01	41.01	35.23	23.76	3,219,800	265
2001-02	54.12	26.73	19.15	3,111,320	256
2002-03	39.25	33.13	27.61	2,734,270	225
2003-04	42.98	26.4	30.62	2,654,700	219
Mean	**45.53**	**28.83**	**25.64**	**2,867,459**	**236**
Std Deviation	**5.76**	**5.72**	**4.30**	**232,132**	**19**

Source- Computed from Tawa Matsya Sangh Annual Reports

According to the Madhya Pradesh Fisheries Development Corporation (MPFDC), the guideline for stocking reservoirs should be about 200 fingerlings per hectare, which Tawa reservoir satisfies.[7] Jhingran and Nataranjan (cited in Sagunnan 1995) recommended a compensation factor for natural mortality at the rate of 50 percent for stocking in presence of predator species in the reservoir. In case of Tawa reservoir, there is no scientific justification available for the present stocking rate. Therefore, there is a need for a detail study of the stocking rate and species composition in order to optimize the production scenario.

Predator and prey relationship

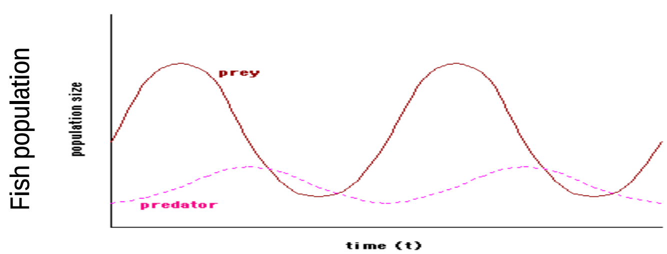
Predators and prey can influence one another's evolution. This relationship is important to understand how communities of fish are structured and sustained. To understand this

[7] The Fish Seed Committee of the Government of India (1996) recommended the stocking rate for reservoir at about 500 fingerlings per hector which is 2.5 more than the guideline set by MPFDC

relationship Alfred Lokta and Vito Volterra in 1920's developed a model independently. This model is known as Lotka-Volterra model. This model is composed of a pair of differential equations that describe predator-prey dynamics in a simplest possible form. The model makes several simple assumptions: 1) the prey population will grow exponentially when the predator is absent; 2) the predator population will starve in the absence of the prey population (as opposed to switching to another type of prey); 3) predators can consume infinite quantities of prey; and 4) there is no environmental complexity (Beals et. al., 1999).

In the case of Tawa reservoir C*. Mrigal, L. Calbasu, Badas* (local name), other minors are preys and catfishes like *A. Seenghala, Samal* and *Padhin* (local names) are predators. If the Model holds true in Tawa reservoir scenario, the predator-prey relationship in Tawa reservoir should follow a cyclical relationship between predator and prey numbers as represented hypothetically in graph figure 3.

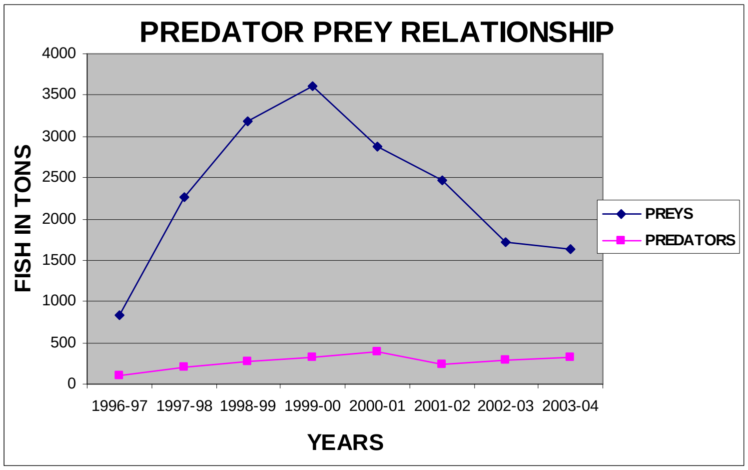
Figure 3 Hypothetical relationships between Predator and prey -Lokta- Volterra



Source- http://www.tiem.utk.edu/~gross/bioed/bealsmodules/predator-prey.html

But predator-prey model in case of Tawa reservoir does not give a clear relationship (figure: 4). The reasons may be largely found in the shortcomings of Lotka-Volterra model due to its reliance on unrealistic assumptions. For example, prey populations are limited by food resources and not just by predation, and no predator can consume infinite quantities of prey. The model does not give a clear relationship because the model only considers natural growth, while in case of Tawa reservoir stocking of fingerlings is an integral part of the fisheries activities. Therefore, in Tawa reservoir case, the growth rate of prey is high enough to overcome the predator-prey relationship model. There is also a possibility that a longer or fragmented time-series data might give a better relationship between predator and prey.

Figure 4 Predator-prey relationships in Tawa reservoir



Source- Computed from Tawa Matsya Sangh Annual Reports

Catch and Stocking Relationship

Tawa reservoir is developed on the principles of capture-cum-stocking fisheries. Therefore, mostly it is desirable to stock the species that may breed until it gets naturalized in the system through auto stocking. This is imperative to meet the long-term objective of obtaining a sustainable yield rate.

In case of catch or yield of any reservoir, it is assumed that there is a direct relationship it with the stocking rate. Choosing the species for stocking and deciding on stocking rate is a sensitive issue, because increase in stock of fish where two or more species use a similar resource, such as food or space, leads to overcrowding and poor growth rate and hence effecting the overall catch. On the other hand, if bigger fishes are needed for better price realization, than the rate of stocking should be reduced and a low but productive number (as well as weight) of fishes will have to be accepted. Similarly, when a marketable size is to be obtained in a shorter period, stocking rate will have to be lowered to allow faster growth. Thus, a desired balance among 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 (Sagunan 1995).

In the case of Tawa reservoir, at present the stocking of fingerlings is at an average rate of 45.53% for *Catla*, 28.83% for *Rohu* and about 25.64 for *Mrigal* (see table: 2). But if one tries to analyze the proportion of catch in similar ways of stocking, it varies widely (table no: 3).

Table 3 Fish Catch in Tawa Reservoir

Year	Catla		Rohu		Mrigal		Total	Yeild (Kg)
	In Nos.	%	In Nos.	%	In Nos.	%	(n=100%)	/ Hactare
1996-97	18,485	52.80	3,305	9.44	13,221	37.76	35,011	7.68
1997-98	54,609	70.28	4,134	5.32	18,958	24.40	77,701	20.24
1998-99	73,642	70.64	5,670	5.44	24,940	23.92	104,252	28.35
1999-00	86,874	77.68	3,614	3.23	21,345	19.09	111,832	32.37
2000-01	58,552	68.20	3,338	3.89	23,958	27.91	85,848	26.94
2001-02	49,954	67.81	3,979	5.40	19,734	26.79	73,667	22.33
2002-03	18,026	44.44	5,472	13.49	17,062	42.07	40,560	16.77
2003-04	21,592	45.72	5,418	11.47	20,220	42.81	47,229	16.26
Mean	**47,717**	**62.20**	**4,366**	**7.21**	**19,930**	**30.59**	**72,012**	**21.37**
St. Deviation	**26169.32**	**12.64**	**998.62**	**3.77**	**3734.58**	**9.02**	**28,845**	**7.91**

Note: In order to capture the actual numbers of catch we divided the total catch of particular specie (which was in kg.) to the average weight of that particular specie.

Source- Computed form Tawa Matsya Sangh Annual Reports

There is a very high level of standard deviation in catch proportions in all the three species. Over the time, the number of *Catla* fish in catch has reduced drastically. Whenever this phenomenon (year 1996-97, 2002-2003 and 2003-04) has happened, it has directly affected the over all production leading to decrease in catch in terms yield/hectare (in Kgs). At the same time, in case of *Rohu,* there seem to be a cyclic fluctuation in the catch. But, *Mrigal,* a local major specie, is very consistent in terms of catch over years. In order to understand the catch scenario as well as behavior of these species, it is important to compare the catch with its stocking rate. We understand from the literature that it takes about 2 years for fingerlings of these species to reach harvesting stage. Therefore, taking the ratio of catch[8] (Time-t) and Stocking (t-2) give us an interesting scenario (table: 4).

[8] Catch is also converted to number considering the average fish weight (in Kgs.) and total catch (in Kgs.)

Table 4 Catch to Stock ratio (%) of different species in Tawa reservoir

Year (t)	Catla	Rohu	Mrigal
	Catch (t)/Stock (t - 2)	Catch (t)/Stock (t - 2)	Catch (t)/Stock (t - 2)
1999 – 00	6.3008	0.7513	2.8305
2000 – 01	4.8915	0.4146	3.0394
2001 – 02	3.7058	0.4085	3.1528
2002 – 03	1.3651	0.4824	2.2305
2003 – 04	1.2822	0.6515	3.3941
Mean	3.5091	0.5417	2.9295
St. Deviation	2.1966	0.1528	0.4405

Source- Computed form Tawa Matsya Sangh Annual Reports

Catla has a catch to stock ratio of about 3.5 percent on an average. However, the concern is the declining ratio of catch to stock over a period of time. *Rohu* has a very low but consistent catch to stock ratio of 0.54 percent over the years. *Mrigal* in this comparison has *a* lower percentage to *Catla* (2.92 on an average). But it has remained very consistent over years. The percentage ratio of catch to stock in all the three species is very low. If Sagunnan's (1995) thumb rule of 50 percent as the mortality rate for stocking of reservoir is considered, this rate seems to be very low. If mortality is computed on the basis of catch to stock ratio in case of Tawa reservoir, it is as high as 97 percent for *Catla* and *Mrigal*, while *Rohu* it is 99.5 percent. The reasons behind this high mortality rate figures may be attributed to the fishing technique used in Tawa reservoir that might have lead to fishing of high number of fingerlings and juvenile fish. There might even be high level of unreported production or high level of production inefficiency, which leads to these skewed results in computing. The catch to stock ratio along with the average weight of fish caught gives a better understanding of these species. Considering 2003-2004 as an odd year, the average weight of *Catla* and *Mrigal* is increasing over the years (Table: 5). Since the average weight of the predator caught is declining over years, it gives an indication that predator are over exploited and they may not be the main culprit behind the high mortality rate. But looking at the average size of fish reported according to the species, (table no. 5) *Catla* and *Mrigal* seem to be well established in the reservoir and there is a possibility that these species are naturally breeding in the reservoir, while Rohu is still struggling to establish itself.

Table 5 Average weights of Fish caught in Tawa Reservoir

Year	Catla Avg. Wt. (Kg)	Rohu Avg. Wt. (Kg)	Mrigal Avg. Wt. (Kg)	Seenghala Avg. Wt. (Kg)	Padhin Avg. Wt. (Kg)
1996-97	2.593	1.297	1.644	1.089	1.967
1997-98	2.99	1.547	1.609	1.093	1.815
1998-99	3.155	1.559	1.762	1.167	2.027
1999-00	3.085	1.523	1.699	1.026	1.762
2000-01	3.367	1.454	1.658	1.005	1.702
2001-02	3.311	1.369	1.719	0.989	1.573
2002-03	4.152	1.407	2.047	0.967	1.276
2003-04	3.036	1.427	1.562	0.873	1.265
Mean	**3.21**	**1.45**	**1.71**	**1.03**	**1.67**
St. deviation	**0.45**	**0.09**	**0.15**	**0.09**	**0.29**

Source-Computed form Tawa Matsya Sangh Annual Reports

Management Regimes of Tawa Reservoir

Tawa is a classic case that underwent different management regime. These include government, partial privatization, private, open access and cooperative management regimes. Therefore, it provides us with the opportunity to analyse the production system under different regimes, which can be used as a benchmark while choosing the right kind of institutions for CPRs like reservoir fisheries management.

Government Management

Tawa dam was completed in 1974 and fish production started in the reservoir in the year 1975 by the state government. The fisheries department managed the fishing form 1975-79 after that it was transferred to Madhya Pradesh State Fisheries Development Corporation (MPFDC) for the period of 15 years (1979-94). During both the forms of government managed regimes fish production was low. During this period the highest reported production was 163.313 Tons/annum. There is even a possibility that the reported production might be quite low than the actual as it happens in most of Government management regime. In 1985-86 the MPFDC gave the marketing and lifting contract to some private individuals, which was the first step they took towards privatization. The production was still under the MPFDC and they tried to increase the production by increase in the stocking[9] rate of fingerlings. The Tawa reservoir has very large water spread area and it becomes difficult to manage the reservoir, therefore there may be a possibility of illegal fishing and poaching activities.

Private management

In 1994-95 the fishing right was given to a private contractor for a period of one year. In this period stocking rate was reduced and there was more exploitation of the fish resources. The sole intention behind the private management being profit maximisation such outcomes are not unexpected. The reported production in Tawa reservoir during this regime was 176.18 ton/annum, much higher than any previous production achieved till than. To prevent illegal fishing and poaching activities the contractor hired musclemen to police the reservoir. During this regime local communities were denied access to the fish resource even for self-consumption. The private contractor introduced Nylon nets of smaller mesh size that used to catch fishes of size below the prescribed limit.

Open access

For a period of one year the government did not create any management regimes for the reservoir (1995-96). During this period, the local people around the reservoir were freely engaged in fishing activities. Since open access regime lacks excludability, the fisherman from adjoining villages also came to fish in the reservoir. This resulted in depletion of the resource and irresponsible harvesting of resources.

TMS and Co-operatives (Collective) Management

After denial of fish resource to the local communities and displacement related problems created unrest among the local communities. This people under the leadership of a non-Government organisation called *Kisan Adibasi Sangathan* (Tribal and Peasants association) organized protest and demanded exclusive right for fishing. As a result of prolonged struggle, the government agreed to their demands and a Memorandum of Understanding (MOU) was signed on October 1996 between MPFDC and *Tawa Visthapit Adivasi Matsya Utpadan Evam Vipanan Sahakari Sangh Maryadit* (Tawa Displaced Tribal Fish Production and Marketing Cooperative Federation Limited). This gave rise to Tawa Matsya Sangh (TMS registered under

[9] No. of fingerlings introduced into the reservoir per annum form the external sources through Aquaculture.

Madhya Pradesh Co-operative Act 1960) or Tawa Fisheries Co-operative. In the initial agreement (1996) TMS got exclusive fishing rights for five years, which was further extended in 2001 for another five years. But the fishing rights of the local tribal and the TMS regime is presently under threat because of project tiger, where there are talks to amalgamate the surrounding Bori and Panchmarhi Sanctuaries and the Satpura National Park.

Presently the TMS has 34 Primary co-operatives and 6 affiliated co-operatives under it. The membership of the fisherman co-operative society is restricted to the project affected people and those residing within a radius of 3 km form the periphery of the reservoir. The responsibility to manage the fish resources including procurement of catch, transportation, marketing and stocking of fingerlings in the reservoir lies with TMS. TMS through cooperation of the villagers are managing the fish resource and preventing illegal fishing[10].

Productivity and Production possibility of fish in Tawa reservoir

In this paper, production is referred as the amount of fish caught on annual basis and productivity as a function of yield per hectare. In case of reservoir fisheries, the production of fish is determined by a set of key environmental parameters, especially the water and soil quality that in turn, is functions of the geo-climatic conditions under which it exists. Thus, the geography, climate, topography and a number of physiographic parameters play a vital role in bestowing the reservoirs their intrinsic productivity potential (Sagunan 1995). Biological along with physical parameter are also important factors that determine the growth rate of fish population in a reservoir. These apart, technology use and socio-economic conditions of the fisher folks play important role in fish production.

In modern era technology like global positioning systems and potential fish zone forecast using satellite data, and mechanized trawlers has boosted the production possibility in the marine fisheries sector. But in case inland fisheries, it is still the traditional high human-power oriented techniques dominate the production scenario. In most of the reservoir, the presence of submerged obstacles such as tree stumps prevents the use of many of active gear. Therefore, choice of the gear is limited on a larger scale to Gill nets. In case of Tawa gill net is the most

[10] Illegal fishing is referred as un-approved used in fishing by the member of the Co-operative and poaching activity carried out by the non-members.

widely used gear for catching different fish species. The fisher folk of Tawa also use a net locally called Goljaal or Hat-Jaal[11]. This net is generally used to catch fish for self-consumption purposes. There are also 'shore seine', locally known as *Maha Jaal*, which normally operated in the summer seasons. This technique requires removing of the tree stumps in the area of operation, which needs collective effort and is practiced by only a few fisher folks. There are also limited hook line operated in the Tawa reservoir, mainly to catch the predator species. In Tawa reservoir 'boat seine' locally known as *Passi Jaal* is only operated by the Bengali fisher folks. It is considered as a skill-oriented technique, since it requires divers if the net get caught in the tree stumps of the reservoir.

Apart form the fish technique the boat capacity also plays an important role in determining the productivity. Most of the boats used in Tawa reservoir are of 2-3 quintal capacity and made of tin. This limits the net weight to be carried along and hence limit the catch amount. Often catch is proportionate to the amount of net used by the fisherfolk. The fishing technology used in Tawa reservoir differs among communities and hence the social factor play an important role in determining the fishing technique used and hence determines the production level.

Technology use largely determines the production relation, at the same time; the investment capacity of the household (e.g. Income) determines the kind of technology the household can afford. Therefore, socio-economic condition of the fisherfolk becomes crucial feature in determining the productivity and production efficiency of the reservoir. In the case Tawa reservoir, the indigenous communities (*Gond and Korkus*) were traditionally forest dwelling and agrarian societies and did fishing mainly as a part time activity for their own consumption needs. When Tawa dam was constructed this people lost their livelihood, and after a long struggle they got fishing right in the reservoir and presently they are operating the fishing activity through co-operative systems. These communities were not commercial or occupationally fisher folk's. This reflects in their use of gill net, one of the most common and affordable technique of fishing. Some, among these communities, over the years have learnt new fishing technique like the shore seine. However, the scale of such operation is very minute.

[11]Gol Jal or Hat Jaal is a circular net with 2-3 meter radius and mesh size is generally 2-3 cm.

Beside the indigenous communities, traditional fisher folks (*Kahars and Dhimars*) who use to fish in the River Tawa before the construction of the dam, were mainly dependent on fishing for their livelihood. These traditional fisher folks are skilled and they use a variety of technique to fish i.e. gill net, Gol net, hook lines etc. Since Fishing is the major occupation of these traditional fisher folks, they devote their full time in fishing activities.

The Bengali fisher folks appear to be the most skilled fishing community of all. They mostly use the Boat seine technique, which has the highest production level compare to other technique. The net used in this technique is also costly and it required 3 boats for operation. A high level of investment is also required to operate this technique. The boat used for fishing in Tawa are made mostly of tin[12] and often needs replacement within a period of 3 years. The nets also need replacement annually, hence a high level of investment is required for fishing in reservoirs.

All these characteristics have sizeable impact on the fish production of the reservoir. However, an analysis based on these characteristics requires in-depth primary level information. Instead, we attempted to understand the production possibility over a period of time using the available time-series data.

Though factors like number of nets, number of boats, and number of working days, for which time-series data were not available. Such data are important in determining the level of effort behind the production level. The data availability like number of fingerling dropped by type was limited only to TMS regime and time-series data of fish prices would have given a better picture of the economic factors affecting the stocking and the production level. However, among other things, management of resources and stocking are crucial factors in determining the productive efficiency of medium and large reservoir. On this count our production frontier analysis, as we will see, gives interesting insight.

[12] These boats are made of wooden frame work with tin mounted on it, hence mostly referred as tin boats

Choice of Basic Model

Initially to evolve criteria for accessing fish production possibility for Tawa reservoir two Bio-economic models were referred, namely, Schaefer model and Fox model. The models are termed as holistic models characterized by consideration of a fish stock as a homogeneous biomass. These models do not take into account growth parameters, such as age structure and rate of growth of individual fish. Schaefer model commonly known as Surplus production model was an attempt to describe a fundamental law of populations of fishes was formulated by Schaefer (1954). In his formulation, fishing is proportional to effort and stock, while biomass is estimated as the ratio between catch per unit of effort and catch ability. Schaefer's formulation is appropriate for situations in which the population tends to be stable, environmental factors are constant and food is limited, e.g. some aquaculture water bodies. Whenever the rate of fishing equals the rate of natural growth, equilibrium will occur (Koeshendrajana and Cacho 2001). A similar model was developed by Fox (1970), in which a logarithmic relationship between catch per unit of effort and fishing effort was introduced. But finally the decision on the type of model to use is often limited by the quality and periodicity of available data. Incase of Tawa reservoir the data was not substantial for using such models.

On basis of the available data and using the logic of fox model, Cobb-Douglas (C-D) production function was used to determine the production possibility frontier. Production frontier represents a production function of the regime where in production function sets a limit or outer bound on the observed levels of output or dependent variable in such a way that no observed value of output is expected to lie above the production function.

In order to choose a particular production function one should follow the logic of the system. In economics literature it is widely accepted that agricultural production follows a path of initial increasing return to scale, followed by diminishing return and at the extreme points it gives a negative returns to scale (Jyotishi 2005). This logic can also be extended for fisheries, where the uncertainties are similar to agriculture. C-D production function is therefore preferred over other production functions, as it adheres to this principle of returns to scale.

Therefore, the production frontier used here is of following specification:

$$Y_t = A \prod_{i=1}^{n} x_{it}^{\beta i} e_{it}$$

This model can be expressed in log linear form as follows:

$$\ln Y_t = \alpha + \sum_{i=1}^{n} \beta_i \ln x_{it} + e_{it} \qquad where\ \alpha = \ln A_i$$

A regression analysis would provide the estimated outcome of the observed values, which can be represented as follows:

$$\ln \hat{Y}_t = \alpha + \sum \beta_i \ln x_{it}$$

Thus, the difference between actual and estimated outcome would provide the values of the error term e_i

$$\ln Y_t - \ln \hat{Y}_t = e_{ti}$$

In a conventional frontier analysis the maximum positive error tem is added to the intercept to get the frontier level of production, represented as

$$\ln \hat{Y}_{t\max} = (\alpha + e_{it\max}) + \sum \beta_i \ln x_{it}$$

The ratio of actual and frontier level of production provides the level of technical (in)efficiency.

Database

24 years time-series observation available starting from 1979-80 to 2003-04, which was compiled form different sources, used for this model. Productivity of the reservoir (kg. per hectare ($LNYLD_t$) was considered as the dependent variable, while the number of fishermen working at Tawa reservoir (as a proxy for effort) ($LNFISHR_t$) and stocking rate per hectare, with a time lag of two years ($LNLAGSTR_{t-2}$) was considered as independent variable (available stock for harvesting). The departmental fisheries by the state and the initial years of MPFDC was considered as government regime($MPFDC_t$). When the MPFDC privatised the

process of lifting and marketing by inviting contracts through tender system, it was considered as a partial private regime. We used the dummy variable of privatisation process as ($LCON_t$) for partial and complete privatisation process. The cooperative regime of TMS was taken as the base to analyse the performance of the above mentioned two regimes.

Results and discussions

Using the earlier mentioned model and above mentioned variables, we attempted to understand the production possibility of the Tawa reservoir and technical efficiency of the system under different regimes. The basic statistics of the variables used in the model are given below in Table 6.

Table 6 Descriptive statistics of the variables

Descriptive Statistics	Mean	Std. Deviation
LNYLD t	2.30	0.84
LNFISHR t	4.81	0.51
MPFDC t	0.14	0.36
LCON t	0.48	0.51
LNLAGSTR t-2	4.68	0.98

$LNYLD_t$ = ln yield per ha. over 1981-82 to 2003-04

$LNFISHR_t$ = ln No. of fishermen.

$LNLAGSTR_{t-2}$ = ln stocking rate per ha. 1979-80 to 2001-2002 (Time lag of 2 year: t-2)

$MPFDC_t$ = Madhya Pradesh Fisheries regime. (MPFDC regime =1, otherwise= 0)

$LCON_t$ = Lifting and Marketing Contract regime. (LCON regime =1, otherwise= 0)

Using the above-described model, we obtained production possibility and technical inefficiency of the Regimes in Tawa reservoir. The results are given in table 7.

Table 7 Factors determining productivity of regimes

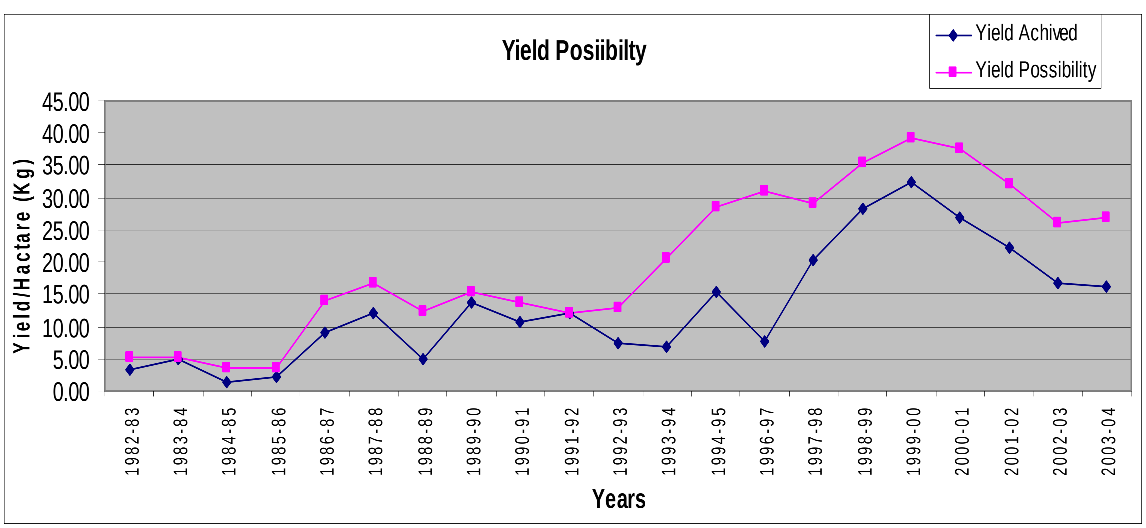
	β- Coefficients	**t-Value**
(Constant)	-2.668	-1.991***
$LNFISHR_t$ – **β1**	1.212	4.112*
$MPFDC_t$ – **β2**	-0.795	-2.030***
$LCON_t$ – **β3**	-0.411	-1.697***
$LNLAGSTR_{t-2}$ – **β4**	-0.120	-0.872

Adjusted R^2 = 0.79

Note * = 1% level of significance, *** = 10% level of significance β- Coefficients of number of fishermen is positive and significant at 1 percent level. Reservoir fisheries being a labour-intensive activity number of fishermen in Tawa determines the effort level in fishing. State controlled ($MPFDC_t$) and lifting and marketing contract ($LCON_t$) regimes show negative relation in the productivity as compared to the base cooperative regime of TMS. This emphasises that the productivity of reservoir faired well during the cooperative regime as compared with the previous two regimes. However, between these two regimes, $LCON_t$ seems to be better determining the productivity of the reservoir then $MPFDC_t$. The stocking rate shows a negative relationship with productivity. The level of significance being high, it is not possible for us to infer anything about this relation. However, as we have discussed earlier that there is high mortality rte of fishes in Tawa, possibility of high unreported production and catch of juvenile fishes would perhaps be the explanatory factors for such relation. These apart, as the stocking is only of a few species, whereas productivity includes all the species, getting a one to one correlation is difficult.

Using this model we computed the frontier level of production. The maximum possible yield was estimated to be 39.35 kg per hectare in the year 1999-00, while the actual yield achieved is about 32.37 kg per hectare. The production possibility in the same year was estimated as 476 tons annually, which is 83 ton higher than the achieved production. Figure 5 shows the actual productivity and productivity possibility.

Figure 5 Productivity achieved and productivity Possibility

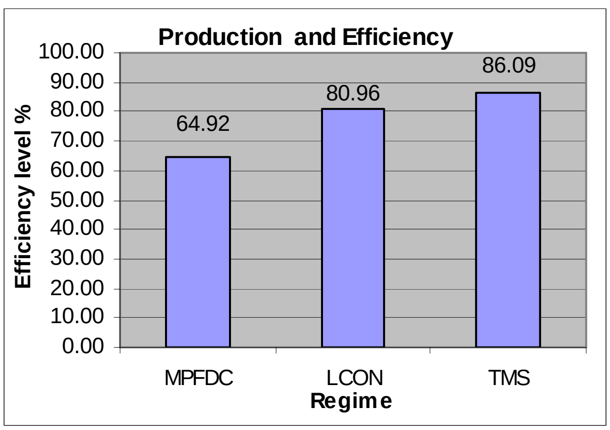


Note – 1995-96 was omitted due to lack of substantial data

Production Efficiency of the management regime

Production efficiency is defined and measured as the ratio of the regimes actual / observed output to its own maximum possible frontier output for a given level of inputs. From actual / observed yield and the estimated maximum yield, production efficiency was computed. It was noted that TMS is most efficient regime followed by the lifting and marketing contract regime (or, partially private regime). The most inefficient regime is $MPFDC_t$, which performs at technical efficiency level of 64.92 percent. While the TMS level of efficiency 86.09 percent, the Lifting and marketing contract ($LCON_t$) is at 81.86 percent level of efficiency. The histogram given in Figure 6 shows the average efficiency of productivity of all the three regimes.

Figure 6 Production Efficiency of different regimes



If we assume that lack of experience might be major determinant that can affect the production level and hence we remove the first year of operation by TMS (1996-97) for computing the Efficiency, then TMS performs at almost 90 percent efficiency level. This proves that TMS compared to other regimes operated in Tawa reservoir, is the most efficient regime followed by the lifting and marketing regime. Since co-operative regimes are not prevalent in most of the reservoir in Madhya Pradesh, the second best option for management fisheries in reservoirs is the lifting and marketing contract regimes. In Tawa case (between 1985 to 1994) when the government concentrated only on production and the marketing was given to a private contractor there was a phenomenal improvement in efficiency (from 64.92% to 80.96%). This gives a clear indication that lifting, transportation and marketing of fish resources performs better if private players participate.

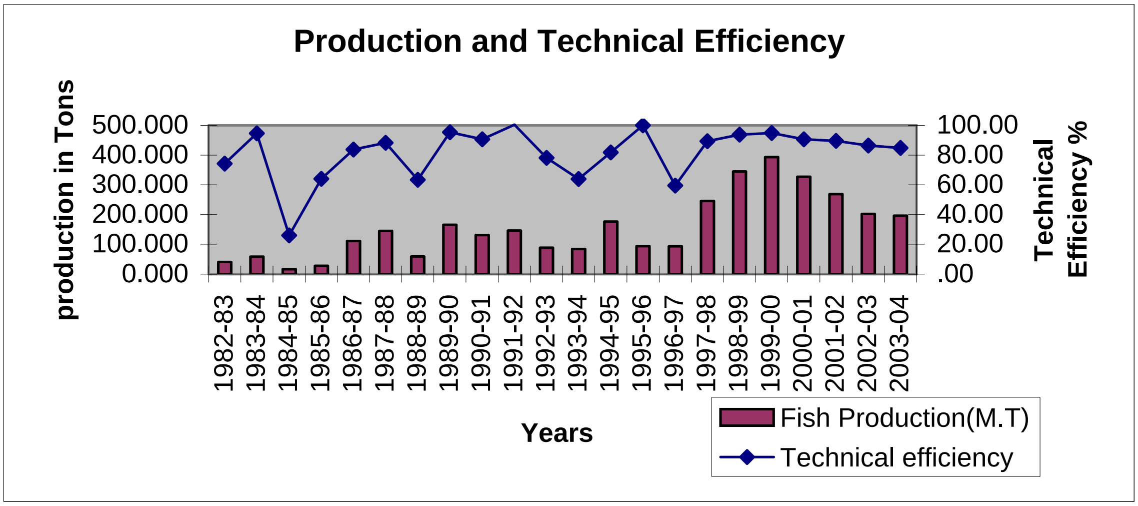
Tawa reservoir is one of the unique cases in India where the displaced people (mostly belonging to the indigenous communities) got the fishing right after a long struggle. Tawa is also unique due to its management under all possible regimes. To asses any regime, its' production performance remains important. With limited available data we tried to analyze the productivity efficiency of Tawa Reservoir. From a theoretical argument we can say that production follows certain path. The economy essentially starts with a low level equilibrium where average production is low due to low level of technological parameters.

Figure 7 Theoretical Flow of Production level and Technical Efficiency

		Low Production (low mean)	High Production (high mean)
Technical Efficiency	Consistent (low Std. Dev.)	1	4
	In-consistent (High Std. Dev)	2	3

This also keeps the standard deviation low that varies only on natural factors. However, technology plays a crucial role in the changes of production scenario. Such changes initially lead to a higher level of standard deviation with a low mean production level. This is a phase of development where technological adoption is not assimilated well in the production pattern. A third phase can be an economy with high mean and standard deviation due to the interface of technological assimilation and uncertainties. A developed stage is one where standard deviation is low with a high level of production (See figure 7). If we compare production and technical efficiency in Tawa scenario, a similar flow is observed. In the case of Tawa reservoir it is broadly observed that between the time periods of 1882-83 to 1996-97 it has low production level and high volatility in technical efficiency. However, after 1996-97 it has moved to high production and high consistent level of technical efficiency (figure: 8).

Figure 8: Productions and Technical Efficiency



These further reinforce the case of TMS regime, which started functioning after 1996-97 have performed much better than the other regimes operated in Tawa Reservoir. Presently TMS has high production as well as high and consistent level of technical efficiency, which is a good indicator of economic growth.

Summary

Fisheries activities in Tawa is interesting, because of the operation of different regimes, various fishing techniques and diverse communities. The intrinsic parameter of the reservoir gives a totally different dimension and hence assessing the production possibility becomes a complicated task. Therefore, with limited available information, the fish resource of Tawa reservoir was analyzed. Fish is a renewable resource and it is realized that for better understanding of fish we need to have a longer time series data of each individual species as well as on intrinsic and external variables so that we can understand any cyclic pattern involved in species. Besides, longer time series helps us to take more relevant variables in a model allowing for adequate degrees of freedom.

Since Tawa reservoir fisheries activity is based on stocking cum capture basis, the stocking rate of fish directly reflects the catch. The present stocking activity was found to be inefficient and has a very high mortality rate. This issue needs immediate attention, so that catch and stocking ratio can be improved. The classic Lokta-Volterra predator-prey relationship is not prominent in

Tawa reservoir due to stocking of fingerlings. It was also observed that predator fish species in Tawa reservoir are over exploited; this might have adverse effects in future.

From our analysis, using limited information, we find that TMS regime seems to be performing better than any other regimes. But there is still a need for a comprehensive study; this would require a lot more input and further research. A micro level household data of individual production would help in creating a clear scenario of the fishing activity. Household level dynamics will help in understanding the activity at micro level leading to inefficiencies and hence remedies can be prescribed to improve the fishing efficiency. Apart from understanding the production and production possibility there is a need to understand the reservoir carrying capacity for fish resource and build a sustainable harvesting scenario for Tawa reservoir. This would require extensive data and research. Since Tawa reservoir is based on stocking cum capture bases, there were exotic species like *Catla* and *Rohu* that are introduced into the reservoir is a matter of environmental concern. Stocking of exotic species have led to elimination of lot of original native species in lot of reservoirs and is presently a major concern regarding Bio-diversity of reservoirs.

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