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Comparative Limnology and Productivity of Two Medium Reservoirs of Uttarakhand, India

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Abstract The limnological studies were conducted in two medium reservoirs of Uttarakhand viz. Dhaura and Baigul with different topographic structures (Dhaura-oval with irregular shore line and Baigul-semicircular with irregular shore line) from June 2006 to May 2007. Fortnightly/monthly sampling was made to observe the physico-chemical quality of water and composition of biotic factors. The water quality was in moderate condition [suitable water temperature (14.2-36.9°C), optimum DO (5.0-8.8 mg l^{-1}), fair pH (7.0–8.7), moderate total alkalinity (70-175 mg l^{-1})]. The study revealed a moderate to fair plankton and fish composition. During study, 30 species of phytoplankton, 15 species of zooplankton and 33 species of fishes were recorded from the these water bodies. The average fish production of Dhaura and Baigul was recorded as 36.8 and 43.9 kg ha^{-1} yr^{-1} respectively. Study of various physico-chemical and productivity parameters reveal that the productivity status of Baigul reservoir is better than the Dhaura and if these water bodies managed properly, production at all the trophic level can be enhanced.

Keywords Biotic factors, Carnivorus, Aquatic vegetation, Trophic level, Reservoirs.

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Introduction

Aquatic water bodies have distinct structures determined by basin morphometry and physical, chemical and biological interactions. The reservoirs, constructed during post independence period, are important for a number of ways viz. irrigation reserves, hydroelectric power and development of fisheries [1]. The management of aquatic resources for enhancing fish production, depends greatly on its limnological characteristics. The abiotic and biotic factors are important and fundamental component of a water body to know the trophic dynamics of an aquatic ecosystem [2]. The limnological characteristics viz. water temperature, transparency, conductivity, amount of TDS, dissolved oxygen, total alkalinity, pH, different nutrients, dynamics of biotic communities, primary and secondary production,

energy flow constitute the major components of hydrology [3]. The size and shape of reservoirs influence their productivity [4]. The state uttarakhand has enormous water area in the form of reservoirs (20,000 ha) [5]. The present investigation is carried out in Dhaura and Baigul reservoirs with different topographic structure, located in Tarai region of Uttarakhand to determine limnological characteristics viz. physico-chemical and biological parameters of the waters for overall management to achieve sustainable fish production. Dhaura is roughly oval in shape with an irregular shore line while Baigul is semicircular with an irregular shore line. The earthen portion of the resrvoirs is made of locally available soil and protected against wave wash by pitching with stones and bricks above the storage level. They have slow vally bottom and have a hot and moist tropical climate, which is influenced by south west monsoon. The soil of the reservoirs is generally composed of silty and clayey loam without gravels and rich in nutrients.

The limnological studies of these reservoirs are based on observations recorded during June 2006 to May 2007 from three fixed sites each in lentic, transition and lotic zones while fish production data were taken from randomly selected 10 fishing boats.

The objective of present study was to assess the limnological and productivity parameters of two reservoirs having different topographic structures with a view to establish correlation, if any between the limnological parameters and fish production.

Materials and Methods

Dhaura and Baigul reservoirs, situated in the Tarai region (sub-mountain tract) of Uttarakhand at 28° 53′ N, 79° 34′ E, 200m ASL and 28° 56′ N,79° 40′ E, 211 m ASL latitude, longitude and altitude respectively, were selected for present study as these are medium sized , productive and approachable (Table 1).

The water quality parameters i.e. water temperature, transparency, conductivity, TDS, dissolved oxygen, total alkalinity and pH were analyzed on the spot following standard methods of analysis. The water transparency was measured as secchi disc transparency. Conductivity and TDS were measured with the help of TDS/conductivity meter. Water sample were analyzed for nitrate, phosphate, silicate, calcium, magnesium using spectroquent ® photometer (Merck make : model -NOVA 60 A). Plankton samples were collected by filtering 100 liters of water through standard plankton net and preserved in 5% formalin. The quantitative study of plankton was made following standard mehods [6]. The organisms were identified following Smith and Smith [7]. Fortnightly fish sampling was conducted in order to record the occurrence and abundance of the fishes. The commercial fisheries were monitored to estimate fish yield and catch per unit effort expressed as catch per boat per day. The fisheries data were recorded in each sampling occasion from 10 randomly selected boats. Each boat was manned with one fisherman and operated the standard gill net (size 50 × 2 m, mesh size from 1.5-7.5 cm).

Table 1. Geomorphological and hydrological features of Dhaura and Baigul reservoirs.

Parameters	Dhaura	Baigul
Latitude	28° 53′ N	28° 56′ N
Longitude	79° 34′ E	79° 40′E
Altitude (m)	200	211
Area of FRL (ha)	1280	2995
Total length of bundh (km)	9.05	15.3
Top width of the dam (m)	4.0	4.8
Maximum height of reservoirs (m)	14.0	13.7
Mean depth (m)	2.2	2.6
Top bundh level (ft)	715.0	696.39
Total catchment's area (km^2)	134.68	305

Results and Discussion

The catchment area of Dhaura and Baigul reservoirs are mainly silty and loamy in nature. The silt-loam sediment originates from deposition of autochthonous and allochthonous particulate matter in the basin. The observations of water quality parameters viz. temperature, conductivity, TDS, pH, dissolved oxygen and free CO_2 were taken on fortnightly basis while nitrate, phosphate, silicate, calcium and magnesium were determined quarterly.

The temperature of surface water ranged from

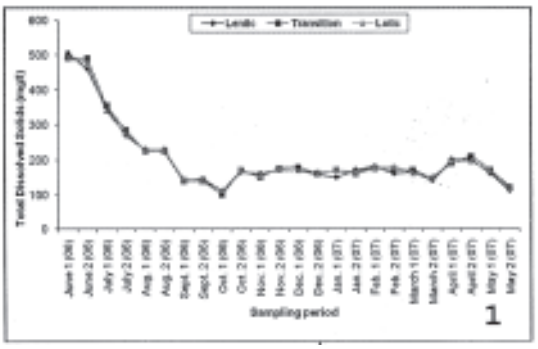

Fig. 1. Fortnightly variation of TDS (mg l^{-1}) in different sectors of Dhaura.

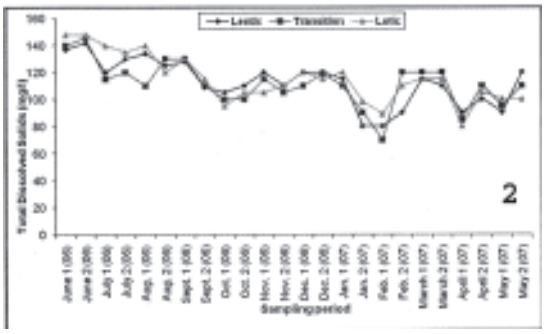

Fig. 2. Fortnightly variation of TDS (mg l^{-1}) in different sectors of Baigul.

lowest of 14.2 °C during January 2007 at lotic sector of Baigul to highest of 35.9 °C during June 2006 in the transition zone of the same reservoir. The water temperature was high in all the sectors of both the reservoirs in May and June. Highest transparency (230 cm) was recorded in the lotic sector of Baigul during March 2007 and lowest (36 cm) in the lotic zone of Dhaura during May 2007. According to Jhingaran [2], water temperature, transparency, TDS, conductivity, pH, alkalinity, dissolved gases (viz. DO, free CO_2) and nutrients viz., nitrate nitrogen, phosphorus, silicate, chloride, iron, calcium, magnesium influence the productivity of the aquatic systems. The water temperature remained high from summer to early autumn after which it declined upto January reaching the lowest level (14.2 °C). Similar patterns of water temperature variation have been described by Sharma et al. [8] in case of subtropical reservoir. Desai [1] and Jhingaran [2] have recorded a close relationship between air and surface water temperature. In this study, also the water temperature fluctuated according to the atmospheric temperature.

In general, water transparency was lower in summer and monsoon periods and higher in post monsoon periods in all the sectors of both the reservoirs. The amount of TDS ranged from 70 to 506 mg l^{-1} with lowest and highest values during February 2007 in transition zone of Baigul and during June 2006 in the lentic zone of Dhaura reservoir respectively (Figs. 1 and 2). The range of variation of TDS in the three sectors of Dhaura and Baigul was found to be from 80 to 506 mg l^{-1} in lentic sector, from 70 to 492 mg l^{-1} in transition zone and from 80 to 490 mg l^{-1} in lotic sector. The TDS concentration was highest during June 2006 in all the zones of Dhaura reservoir. There is a seasonal variation of water transparency due to the differential amounts of suspended solids, algae, silt and illumination [8]. Low values of water transparency during monsoon season are caused by large amount of silt being supplied into the reservoirs through catchment area [9]. On other hand, the high values of transparency during winters (above 100 cm) resulted due to lack of surface run off and minimum disturbances in water column. The concentration of TDS has been considered as an index of productivity of the aquatic environments [2]. Mishra et al. [10] and Arhonditsis et al. [11] have observed a significant relationship between TDS and quantities of plankton, botton fauna and fish fauna. In the present study, the TDS ranged between 100 and 506 mg l^{-1} in Dhaura and between 70 to 148 mg l^{-1} in Baigul with higher values during summer and monsoon months while the lower levels were noted in winter seasons. According to the criteria set by Jhingaran [2] reservoirs with TDS of 50 mg l^{-1} are productive. Thus with TDS of 70-148 mg l^{-1} in Baigul and 100-506 mg l^{-1} in Dhaura, the water system is productive.

The fluctuation in water pH was observed between 7.0 and 8.7. In generral, the pH values were lower during the rainy season or cloudy day than

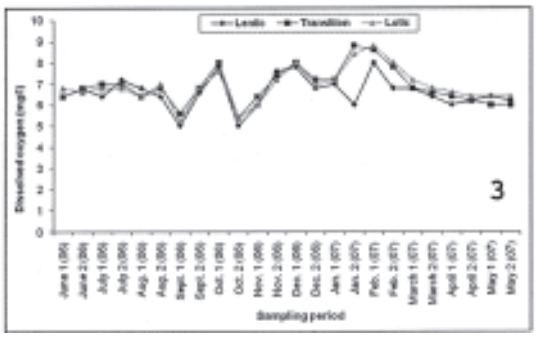

Fig. 3. Fortnightly variation of DO (mg l^{-1}) in different sectors of Dhaura.

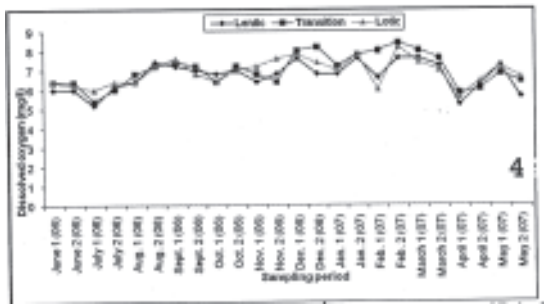

Fig. 4. Fortnightly variation of DO (mg l^{-1}) in different sectors of Baigul.

those recorded during winters and summers on sunny days. The maximum pH value (8.7) was recorded in lentic zone of Dhaura during January 2007. Deorari [12] and Mishra et al. [13] have reported that a pH range of 7.2 to 8.5 favors the growth of plankton. The pH values above 9.0 are not conducive for plankton and fish production [2]. He has also stated that moderately alkaline nature of reservoir is favorable for fish production. Thus, Dhaura and Baigul reservoirs with favorable pH regime are suitable for fish growth.

The concentration of dissolved oxygen varied from 8.8 mg l^{-1} (in transitional zone (January 2007) and lotic zone (February 2007) of Dhaura) to 5.0 mg l^{-1} (in the lentic zone of Dhaura during September 2006 and October 2006). The DO fluctuated between 5.0–8.0 mg l^{-1} in lentic sector, 5.4-8.8 mg l^{-1} in transitional zone and 6.0-8.8 mg l^{-1} in lotic sector. In general an increasing trend of dissolved oxygen was observed in post monsoon season which continued till winter beyond which it declined again (Fig. 3 and 4). The dissolved oxygen concentration in Dhaura and Baigul reservoirs was generally observed higher during winters (up to 8.8 mg l^{-1}). The increased concentration of dissolved oxygen during this period might be due to increased rate of photosynthesis. The same trend was also found by Mishra et al. [13] in their studies.

The total alkalinity showed a wide range of variation. The highest value (175 mg l^{-1}) was recorded during January 2007 in lotic sector of Dhaura and the lowest value (70 mg l^{-1}) was found in lentic sector of Baigul during January 2007 (Figs. 5 and 6). The carbonates and bicarbonates are largely predomi-

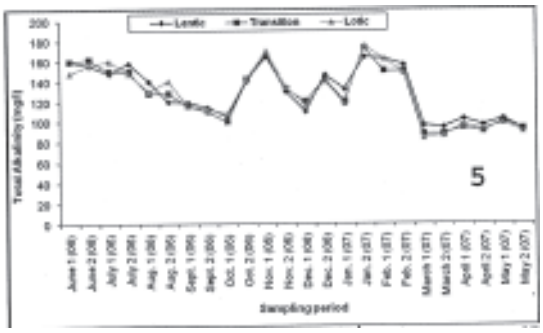

Fig. 5. Fortnightly variation of total alkalinity (mg l^{-1}) in different sectors of Dhaura.

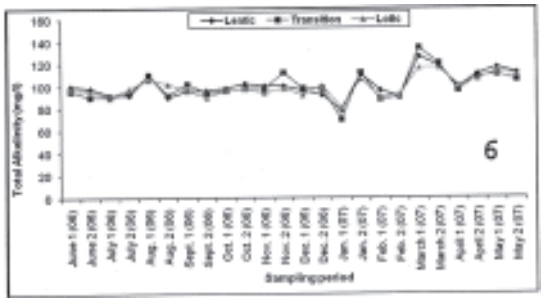

Fig. 6. Fortnightly variation of total alkalinity (mg l^{-1}) in different sectors of Baigul.

Table 2. Quarterly variation of nitrate-nitrogen (mg $^{-1}$) in different zones of Dhaura and Baigul reservoirs.

Months	Dhaura (nitrate in mg l^{-1}) Lentic zone	Tran-sition zone	Lotic zone	Baigul (nitrate in mg l^{-1}) Lentic zone	Tran-sition zone	Lotic zone
Jun (2006)	0.4	0.42	0.38	0.5	0.45	0.45
Sep (2006)	0.2	0.25	0.24	0.6	0.6	0.5
Dec (2006)	0.7	0.6	0.65	0.7	0.65	0.6
Mar (2007)	0.35	0.4	0.35	0.56	0.6	0.5
May (2007)	0.45	0.35	0.38	0.4	0.38	0.3

Table 3. Quarterly phosphate variation (mg l^{-1}) in different zones of Dhaura and Baigul reservoirs.

Months	Dhaura (phosphate in mg l^{-1}) Lentic sector	Tran-sition zone	Lotic sector	Baigul (phosphate in mg l^{-1}) Lentic sector	Tran-sition zone	Lotic sector
Jun (2006)	0.16	0.12	0.1	0.22	0.25	0.2
Sep (2006)	0.05	0.05	0.04	0.06	0.09	0.1
Dec (2006)	0.13	0.12	0.13	0.09	0.085	0.1
Mar (2007)	0.07	0.08	0.082	0.1	0.12	0.11
May (2007)	0.11	0.095	0.1	0.1	0.09	0.1

nant ions in most of the freshwaters of world [2]. In the present investigation, the amount of total alkalinity ranged from 70 to 175 mg l^{-1}. It was high during winter in both water bodies. This may be attributed to the presence of inflowing nutrients along with river water and drainage from catchment area. During winters, due to less utilization of these nutrients by phytoplankton, the concentration was increased. The findings of several workers [2, 13] support the increased concentration of total alkalinity during months other than the monsoon months.

The concentration of nitrate nitrogen was maximum (0.7 mg l^{-1}) in lentic sector of Dhaura during December 2006 and minimum (0.2 mg l^{-1}) in the same sector of same reservoir during September 2006 (Table 2). The changes in phosphate content appeared to follow the trends of nitrate. The range of phosphate in lentic, transition and lotic zones were 0.05 – 0.22 mg l^{-1}, 0.05 –0.25 mg l^{-1} and 0.04 – 0.13 mg l^{-1} respectively with overall variation from 0.04 mg l^{-1} (in the lotic sector of Dhaura during September 2006) to 0.25 mg l^{-1} (in the transition zone of Baigul during June 2006) (Table 3). The pH of natural water is considered as an index of environmental conditions. It affects the biochemical reactions and controls the activities and distribution of aquatic fauna and flora [4]. The nitrogenous compounds in water bodies are derived to an appreciable degree from the atmosphere and decomposition of dead plant and animal products [14]. Nitrate nitrogen levels in the aquatic systems play an important role in primary production. In the present investigation, the concentration of nitrate -nitrogen fluctuated between 0.2 and 0.7 mg l^{-1} . The highest values of nitrates during December may be attributed to the inflow of allochthonous organic matter through river drainage [15]. Phosphorus is often considered as the most important nutrient for the productivity in aquatic ecosystems [2, 4]. In the present study, the phosphate concentrations were detected to be low (about 0.05 mg l^{-1}) in the monsoon but higher levels (about 0.1 mg l^{-1}) were recorded during the winter in both the reservoirs. The increase in the phosphate during winter may be attributed to reduced assimilation in photosynthesis. According to Sugunan [4], the macrophytes and phytoplankton play an important role in reducing the phosphate concentration during monsoon. Accordingly, oligotrophic–mesotrophic lakes had a total phosphate content of 8 µg l^{-1} while mesotrophic – eutrophic ones had above 17.6 µg l^{-1}. The average phosphate content of Dhaura and Baigul reservoirs was in the range of 0.04 and 0.25 mg l^{-1} (40 and 250 µg l^{-1}) which would thus fall in the category of eutrophic water bodies [2].

Silicate content in these reservoirs ranged between 1.7 and 5.1mg l^{-1} , which was invariably higher in all the sectors of Dhaura reservoir owing to excess influx of these ions into river water from surface flow. Diatoms and some specific species of algae consume silicon during the periods of their active growth [16,17]. In Baigul reservoir, the dominant population of diatoms in winter and summer seem to have a role in reducing the silicate concentration. In the present study, the calcium concentration varied from 23-52 mg l^{-1} with upward trends during summer season Jhingaran [2] and Sugunan [4] attributed the increase in Ca concentration in winter

to decrease in pH, which changes it into insoluble from. In this study, the increase of Ca concentration in summer may be due to less utilization by primary producers. Magnesium content of Dhaura and Baigul reservoirs was recorded between 5.2 and 22. 1 mg l^{-1} The normal range of magnesium in aquatic water bodies is between 20 and 200 mg l^{-1} [4]. In the present study, the concentration of Mg was found below normal due to excessive utilization by macrophytes. A perusal of the account presented above it may be inferred that the water parameters of Dhaura and Baigul are suitable from the productivity point of view.

Plankton

A total of 30 species of phytoplankton belonging to chlorophyceae viz. *Pediastrum* spp, *Scenedesmus quadricuada, Chlorella vulgaris, Spirogyra* sp, *Zygnema* sp, *Volvox* sp, *Eudorina elegans, Cosmarium* sp, *Mougeotia* sp and *Ankistrodesmus falcatus;* bacillariophyceae viz. *Cymbella* sp. *Synedra* sp, *Navicula viridula, Melosira granulate, Nitzschia palea, amphora ovalis, Pinularia* sp. *Fragillaria crotensis* and *Gomphonema* sp; cyanophyceae viz. *Microcytis aeruginosa, Anabaena spiroides, Oscillatoria* sp, *Nostoc* sp, *Spirulina* sp and *Aphanocaspa* sp and dinophyceae viz. *Gymnodinium* sp, *Ceratium* sp and *Peridinium* sp were observed from Dhaura and Baigul reservoirs during the investigation period. A total of 15 species of zooplankton including 5 species each of *rotifera* viz. *Keratella tropica, Filinia longiseta, Leanec, Brachionus calciferous and Notholca;* cladocera viz. *Daphnia, Moina, Clydorus, Bosmina* and *Bosminopsis* copepoda viz. *Cyclops Diaptomus, Mesocyclops leuckertii, Eucyclops* and *Thermocyclops* were collected during the period of present study. Deorari [12] recorded 33 species in Dhaura reservoir. Mishra et al. [3] have emphasized that species richness is lower in tropical water bodies than the temperate ones Bergor [18] and Lashari et al. [19] determined the direct role of environmental factors and climatic variation on phytoplankton community. The observations obtained in the present investigation are similar to the above mentioned reports. It could, therefore be inferred that the phytoplankton community in Dhaura and Baigul reservoirs changes frequently during different seasons owing to abruptly changing environmental factors. Mishra et al. [10] had also recorded a similar pattern of change in phytoplankton community in different freshwater bodies.

The zooplankton community of Dhaura and Baigul reservoirs resembled the species spectrum of tropical reservoirs. The total standing crop of zooplankton showed more or less bimodal fluctuation with first peak during October-November and second one during February–March in Dhaura and Baigul. The similar pattern of seasonal variation in zooplankton standing crop has also been reported by Deorari [12].

Fish catch

The data of fish catch and population density were recorded from ten boats that were selected randomly. A total of 21 genera of 33 fish species comprising of Indian major carps, minor carps, cat fishes, weed fishes and other fishes and were recorded from Dhaura and Baigul during the investigation period (fishing was banned during monsoon season). The Indian major carps were represented by *Labeo rohita, L. calbasu, Cirrhinus mrigala* and *Catla catla,* minor carps by *Labeo gonius, L. bata* and *Cirrhinus reba,* cat fishes/ other carnivorus fishes by *Wallago attu, Mystus* spp., *Channa* spp. *Heteropneustes fossilis, Notopterus notopterus, Nandus nandus, Mastacembelus* spp. and *Macrognathus aculeatus* and weed fishes by *Puntius* spp*., Osteobrama cotio, Gadusia chapra, Oxygaster* spp., *Rasbora daniconius, Xenentodon cancila, Chanda* spp*., Colisa fasciatus* and *Glassogobius giuris.*

The annual fish catch of Dhaura and Baigul reservoirs (calculated from the data of experimental fishing and Department of Fisheries, Government of Uttarakhand) are given here. An annual catch of 47065 kg and 131535 kg was obtained in Dhaura and Baigul reservoirs respectively. The catch was highest during December 2006 in both the reservoirs. The catch of Dhaura was dominated by *L. gonius, C. mrigala* and *C. catla* while *L. gonius* and *N. notopterus* were dominant in Baigul fish catch. The average fish production during the year of investiga-

Table 4. Comparative biodiversity and productivity of Dhaura and Baigul reservoirs.

Parameters		Dhaura	Baigul
Phytoplankton			
1.	Maximum number of species	30	30
2.	Range of population density (cells l^{-1})	28201 - 185765	85693 - 218229
3.	Average gross primary productivity (mg C m^{-2} day^{-1})	777.17	808.83
Zooplankton			
1.	Maximum number of species	15	15
2.	Range of population density (units l^{-1})	1093 - 7333	952 - 11581
Fishery			
1.	Maximum number of species	28	31
2.	Dominant fish species	*Labeo gonius, Cirrhinus mrigala*	*Labeo gonius, Notopterus notopterus*
3.	Total fish production (2006 - 07) (Quintal)	470.65	1315.35
4.	Fish production (kg ha^{-1} yr^{-1})	36.77	43.92

tion was calculated as 36.77 and 43.92 kg/ha/yr from Dhaura and Baigul respectively (Table 4). The annual fish catch of Dhaura was dominated by *L. gonius, C. mrigala* and *C.catla* while *L. gonius* and *N. notopterus* were dominant in Baigul reservoir. The average fish production during the year of investigation was calculated as 36.77 and 43.92 kg/ha/yr from Dhaura and Baigul respectively (Table 4). Deorari [12] reported an average fish production of 21.3 kg ha^{-1} yr^{-1} in Dhaura reservoir. The average fish production of Dhaura and Baigul (36.77 kg ha^{-1} yr^{-1} and 43.92 kg ha^{-1} yr^{-1}) is higher than the other reservoirs of India [1] which could be further increased by employing better management practices. The higher fish production in Baigul reservoir may be due to its topographic structure (semicircular with irregular shoreline) which supported the better natural fish production.

The present study reveals the status of water quality, plankton diversity and fish production in Dhaura and Baigul reservoirs. The limnological features of both the reservoirs are suitable for better fish production. The productivity of Baigul reservoir is better than the Dhaura as it has suitable topographic structure and better water quality parameters. There are some basic problems viz. over population of *Microcystis aeruginosa*, macrophytic vegetation, weed fishes, poor stocking of commercial fishes, illegal fishing during breeding period, poaching, poisoning, siltation. These problems are in preliminary stage and may be controlled by applying important management practices such as conservation of habitat and fish stock, stocking of omnivorus fishes, rational exploitation of predatory fishes.

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