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Assessment the present status of fish diversity in relation to physicochemical characteristics of Nanaksagar reservoir of Uttrakhand

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Abstract
The present study was conducted to assess the limnological characteristics and ichthyofaunal diversity in Nanaksagar reservoir, located in Tarai region of Uttarakhand. Along with water quality parameters and fish communities was done in Nanaksagar reservoir. Monthly samplings were conducted at three selected sites during August 2016 to March 2017. A total number of 30 species of fishes were recorded during the study period. The fish data is subjected to species diversity analysis. As per values of Shannon (2.118 – 2.612) and Simpson diversity (0.822 – 0.8954) indices fish community of the reservoir is diverse. The range of Margalef and Menhinick species richness indices (3.253 – 3.782 and 0.9183 – 1.065, respectively) indicates moderate fish species richness. The evenness index was maximum (0.5453) in month of March, 2017 showing maximum dominance of different species. The average fish production of Nanaksagar reservoir during investigation period was calculated as 45.07 kg/ha. Fish production was found to be positively correlated with total alkalinity (0.92), DO (r=0.84), pH (r=0.79), transparency (r=0.47) and specific conductivity (r=0.18).

Keywords: Limnological, icthyofaunal, nanaksagar, species diversity, evenness

1. Introduction
Indian marine fishery resources have already been overexploited due to increase in number of fleet and increase in fishing time. Inland fisheries resources are plentiful and those are quite diverse that comprise an extensive network of 29000 km rivers; 128000 km ha man made canals, 3.15 million ha of reservoirs; 0.3 million ha of estuaries; 2.36 million ha of pond and tanks; 0.19 million ha back water and lagoons; 0.2 million ha of floodplain wetlands, 0.72 million ha of upland lake [1]. The reservoirs are an important component of inland aquatic resources of India, known for their rich biogenic production potential [2] which can be significantly augmented based on information on diversity of fish-food organisms. The health of an aquatic ecosystem depends on the abiotic properties of water and the biological diversity of the ecosystem [3]. The quality of any water resource is measured in the form of its physico-chemical parameters. The changes in the physico-chemical parameters tend to change the living biota, especially in the numbers, diversities and distributions in that ecosystem [4, 5]. The State of Uttarakhand is endowed with plenty of freshwater resources in the form of rivers, lakes, reservoirs etc. The Tarai region of the State has many small (<1000 ha) and medium sized (1000-5000 ha) reservoirs like Dhaura, Haripura, Baigul, Baur, Tumaria, Nanak Sagar and Sarda Sagar [6]. These water bodies support valuable piscine diversity. The average fish production rate in the reservoirs of Uttarakhand is about 25 kg/ha which can be increased up to 200 kg/ha by proper scientific fisheries management [7]. Nanak Sagar reservoir is located near the Town Sitarganj across the river Deoha, with a catchment area of 570 km2. It was constructed in the year 1962. The analyses of catch statistics in the light of prevailing ecological conditions suggest the need for eco-friendly fishery management to enhance fish production. According to Natarajan (1976) [8], fertility of the reservoirs is dependent more on the nature of catchment area, than on the basin soil. Species diversity is a key indicator of the complexity and health of ecological communities, providing information concerning the richness of interspecific interactions, ecosystem stability and quality of environmental conditions.
Therefore the present study was done on limnology and Ichthyofaunal diversity in Nanak Sagar, a medium reservoir in Tarai region of Uttarakhand.

The study will help in assessing the current status of limnology and fisheries, providing necessary inputs for improving the fisheries management in the reservoir.

2. Materials and Methods

The Nanak Sagar reservoir is situated at latitude of (79,50,34'E, 28,57,20'N)near Sitarganj. Three sites of the reservoir (S1, S2 & S3) were selected for regular sampling of limnological parameters and ichthyofauna. Site S1 in Nanaksagar Dam is the Baoli Sahib, it is about one and a half km from Gurudwara Nanakmatta Sahib. This place is also used as Boat stand and large number of people come here daily. The next site is S2 which is known as Kati pulia which is about 500m from site S1 and has a small drainage for agriculture purpose. The last site was the Dam area (S3) which is about 500 m from site S2 and 1000 m from site S1. Water quality was assessed by regular fortnightly sampling throughout the study period for estimation of water temperature, transparency, conductivity, TDS, pH, dissolved oxygen, free CO2, alkalinity, nitrate, phosphate following standard methods of APHA (2012) [9]. The varieties of fishes caught from the Nanak Sagar reservoir were identified with the help of Day (1878) [10], Jayaram (1981) [11] and Jhingran (1991) [12]. Margalef's richness index [13], Menhinik index [14], Simpson's diversity index [15], Shannon's diversity index [16], Sheldon evenness index [17] and Dominance index these all indices have been calculated by using basic programme PAST to know the diversity of fish fauna of the Nanak Sagar reservoir. The observed values of all the abiotic and biotic components was subjected to statistical analysis [18].

3. Results and Discussion

3.1 Physical characteristics of water

The data on the monthly variation in physiochemical parameter of different sites of Nanaksagar reservoir is presented in (Table 1-3). The limnological profile of the Nanaksagar reservoir is greatly influenced by intensive anthropogenic activities. Physiochemical parameters like temperature, transparency, conductivity, TDS, pH, dissolved oxygen, free CO2, alkalinity, nitrate, phosphate are known to affect ecosystem characteristics [19].

3.2 Fishery and Production

Nanaksagar reservoir has a rich assemblage of naturally occurring fish species. Fish fauna of Nanaksagar reservoir comprised of 30 species belonging to 7 orders, 9 families and 22 genera of major carps, minor carps, catfishes / carnivorous fishes and weed fishes. Singh and Sharma (1993) [20] reported 34 fish species in Nanaksagar reservoir. Deorari (1993) **[21]** reported 35 fish species in Dhaura. Mishra *et al.,* (2014) [22] reported 33 fish species comprising 8 species of carps, 14 species of cat fishes/other carnivorous fishes and 11 species of weed fishes in Dhaura and Bailgul reservoirs. Ananya *et al.,* (2014) **[23]** reported 39 fish species classified under 25 genera and 10 families in Sarni reservoir. Out of these the important fishes include *Catla catla, Labeo rohita, Cirrhinus mrigala, Labeo calbasu, Ctenopharyngodon idella, Cyprinus carpio, Labeo gonius, Notopterus notopterus, Mystus spp, Channa spp, Wallago attu* etc. Total, regional and local diversity varied with spatial gradients. In Nanaksagar the fish taxa varied from 25 (During September) to 30 (During March). The Nanaksagar reservoir is infested with 90% submerged aquatic vegetation (*Potamogeton, Hydrilla, Vallisneria and Chara*) Oliveira *et al*., (2004) [24] stated aquatic plants are important habitats for fish because they increase spatial heterogeneity and feeding resource availability in reservoirs. This finding supports the more number of fish species recorded from the Nanaksagar reservoir. According to Johal and Rawal (2005) [25] altitude as well as slope gradient exert the primary influence on the abundance and distribution of fish species. It is however very difficult to pin point one single factor for the fish species richness and diversity in the reservoirs to classify them all these factors are interrelated and cannot be overlooked for the distribution and abundance of the various fish species. The family Cyprinidae with 15 different species dominated the sample. According to Nelson (2006) [26] the greatest freshwater diversity in Cypriniformes and Siluriformes in the freshwater habitat. Majority have high commercial importance as food and ornamental fishes. Among the total fish species recorded, 15 belongs to Cypriniformes, 5 species from Siluriformes, 3 species from Perciformes, 3 species from Ophiocephaliformes, 2 species from Clupeiformes and rest of orders were represented by single species. Similar observations has also been made by Singh (2001) [27] and Basavaraja *et al*., (2014) [28]. The presence of economically important and cultivable fishes like *Catla catla, Labeo rohita, Cirrhinus mrigala, Ctenopharyngodon idella, Cyprinus carpio, Labeo calbasu, Wallago attu, Mystus spp., Channa spp., Labeo gonius and Notopterus notopterus* shows that the reservoir can be exploited for commercial production of fishes for better improvement of socio economic condition of local people. The details of fish fauna of the reservoir, recorded during the course of the present investigation, are given in table 4. The annual fish catch of Nanaksagar reservoir (calculated from the data of experimemntal fishing & Department of Fisheries, Government of Uttarakhand) is given here. The seven months catch of 2,20,867.42 kg was obtained in the Nanaksagar reservoir. The average fish production of Nanaksagar reservoir during investigation period was calculated as 45.07 kg/ha from seven month catch data. The present study indicates that the water quality of the selected reservoir is within normal condition but the fish production level is not so satisfactory due to imbalanced trophic structure.

3.3 Fish Diversity Indices

The monthly catch data of fish from Nanaksagar reservoir was used here to estimate species richness, diversity and evenness indices (Table 5). There was variation in occurrence in number of fish species in different months. Number of species recorded varied from 25 during in the month of September, 2016 to 30 during in the month of March, 2017. The richness indices Margalef and Menhinick ranged from 3.253 (during the month of September, 2016) to 3.782 (during the month of March, 2017) and 0.9183 (during in the month of November, 2016) to 1.065 (during September, 2016), respectively. The Shannon's diversity index was least (2.118) during the month of October, 2016 and highest (2.612) during March, 2017. The Simpson index was also less (0.822) in the month of February, 2017 and high (0.8954) during March, 2017. This indicates some changes which led to an increase in dominance of fewer species during the month of March, 2017. The evenness index is maximum (0.5453) in month of March, 2017 and it is showing maximum dominance of different species. During the course of study, the fish taxa varied from 25 to 30 (Table 6). The Margalef richness index was maximum (3.782) in March 2017 while Menhinik was highest (1.065) in September 2016. Shannon's diversity index showed higher values (2.612) during March 2017. A community

become more dissimilar as the stress increases and accordingly species diversity decrease due to resulting of poor water quality. Plafkin *et al.,* (1989) [29] stated dominance of relatively few species in community indicates environmental stress. However, the Shannon's index value (2.118-2.612) obtained indicates low pollution in the water body. In the present study, the Shannon's index value is 2.612 in March, which indicate that the structure of habitat is moderately stable according to Shannon (1949) [16], who mentioned that, the index value above 3 indicate that the structure of habitat is stable and balanced; if the values below 1 indicate that there are pollution and degradation of habitat structure. The low value (0.822) of Simpson index indicates an increase in dominance of fewer species in the month of February variation in water quality. Simpson index is commonly used for measurement of diversity, with value ranging 0 to 1. Shannon's diversity index also shows high fish diversity in Nanaksagar reservoir. Month of March 2017 shows maximum diversity where even distribution of ichthyofauna shows favourable condition. A scale of pollution in terms of species diversity (0.0-1.0 heavy pollution, 1.0-2.0 moderate, 2.0-3.0 light, 3.0-4.5 shows slight pollution) has been described by [30]. According to this scale, the Nanaksagar reservoir with species diversity range of 2.118 to 2.612 falls under the category of light polluted water bodies. In the present study the evenness value is 0.5453, which indicate the individuals uniformly distributed. According to Sheldon (1969) [17] who stated that, when the (E) value is getting close to 1, it means that the individuals are distributed equally. Our findings were supported by research findings of Mishra *et al*., (2014) **[22]** and Ananya *et al*., (2014) **[23].** The observation of Ferreira and Petrere (2007) [31] on diversity and equitability indices showed different results when biomass or number was considered. Medeiros *et al*., (2006) [32] documented that there is variation in fish assemblage composition in river of Brazilian. Carol *et al.,* (2006) [33] observed the relationship between quality of water and fish assemblages in European reservoir and found that there was no significant effect on water quality on overall richness or Shannon's diversity, suggesting low species richness is a good indicator of cultural eutrophication in reservoirs than fish diversity. Suvarnaraksha *et al.,* (2012) [34] documented that the geo-morphological parameters were more significant in predicting both species richness and Shannon diversity index than the physico-chemical parameters, in which altitude was the most significant. Distinct patterns of fish assemblage along the longitudinal river gradient reflects the homogenous spatial units within the river basin [35, 36]. Vijaylaxmi *et al.,* 2010) [37] stated fish assemblages have widely been used as ecological indicators to assess and evaluate the level of degradation and health of water bodies at various spatial scales. Basavaraja *et al.,* (2014) [28] documented maximum number of species from low land area of Anjanapura reservoir, Karnataka.

3.4 Relationships between fish production and physicochemical characteristics

In the present study the fish production was found to be positively correlated with DO (r= 0.84), total alkalinity (r= 0.92), transparency (r= 0.47), pH (r= 0.79) and specific conductivity (r= 0.18) but negatively correlated with nitrate (r= -0.75), phosphate (r= -0.62), CO2 (r= -0.80), temperature (r= -0.77) and TDS (r= -0.66) (Table 6). Hrbacek 1969 [38] and Liang *et al.,* 1981 [39] stated that the correlation is even better than the relationship seen between fish yield and primary production in stocked ponds. Variation in fish production during different months was found to be significant ($p< 0.05$).

Table 1: Monthly variations of physicochemical parameters of Nanaksagar reservoir in S1

Parameters	August	September	October	November	December	January	February	March
Temperature	33	34	29.9	24	21	17.9	25	26.1
Transparency	67.9	87.9	130	187.7	166	148.4	117.5	101.5
Electrical Conductivity	336	221	246	225	260	245	295	320
TDS	156	149	101	105	120	113	92.5	111
pH	7.4	7.6	8	8.1	8.3	8.7	8.4	7.4
DO	4.4	3.2	6.4	6.5	6.5	8.2	9.5	9
CO_2	6	5.3	3.5	3.5	2.4	2	0.2	0
Alkalinity	65	68	74	85	110	115	140	123
Phosphate	0.45	0.64	0.52	0.376	0.34	0.32	0.249	0.232
Nitrate	0.081	0.2	0.13	0.075	0.065	0.064	0.053	0.047

Table 2: Monthly variations of physicochemical parameters of Nanaksagar reservoir in S2

Parameters	August	September	October	November	December	January	February	March
Temperature	32	33	29.7	23.5	21	16.9	24.7	25.9
Transparency	72.5	91.7	134.6	194.7	171	155.5	125	109.9
Electrical Conductivity	325	119	330	220	255	243.9	293.9	316
TDS	138	138	97	101	110	110	91.7	108
pH	7	7.4	7.3	7.8	8.1	8.3	8.1	7.2
DO	5.5	5.8	6.5	6.5	7.5	8.5	9.6	9.2
CO_2	3	2.5	2.5	2.3	2	1	0	0
Alkalinity	60	63	70	80	100	112.5	136	120
Phosphate	0.4	0.6	0.47	0.371	0.3	0.28	0.245	0.224
Nitrate	0.08	0.178	0.124	0.072	0.062	0.061	0.052	0.043

Table 3: Monthly variations of physicochemical parameters of Nanaksagar reservoir in S3

Parameters	August	September	October	November	December	January	February	March
Temperature	32	33.5	30	23	21	17.5	24.9	26
Transparency	68	88	132.1	190.5	168.7	151.6	120.3	103.9
Electrical Conductivity	246	118	290	224	261	244.6	294.7	326
TDS	142	141	99	102	115	112	92	110

pH	7.2	7.7	7.7	8	8.25	8.6	8.3	7.3
DO	5	5.6	5.5	5.5	7.3	8.3	9.5	9.1
CO_2	4.5	2.7	3.3	2.5	2.2	1.5	0.1	0
Alkalinity	62	65	72	82	102	114	138.5	118.5
Phosphate	0.42	0.62	0.5	0.373	0.31	0.3	0.247	0.228
Nitrate	0.078	0.18	0.129	0.071	0.064	0.062	0.05	0.045

Table 4: Fish fauna of Nanaksagar Reservoir

Scientific name	Local name	Class	Order	Family
Catla catla (Ham.)	Bhakur	Actinopterygii	Cypriniformes	Cyprinidae
Labeo rohita (Ham.)	Rohu	Actinopterygii	Cypriniformes	Cyprinidae
Cirrhinus mrigala (Ham.)	Nain	Actinopterygii	Cypriniformes	Cyprinidae
Ctenopharyngodon idella		Actinopterygii	Cypriniformes	Cyprinidae
Cyprinus carpio		Actinopterygii	Cypriniformes	Cyprinidae
Labeo gonius (Ham.)	Khursa	Actinopterygii	Cypriniformes	Cyprinidae
Wallago attu (Ham.)	Lachi	Actinopterygii	Siluriformes	Siluridae
Mystus seenghala (Sykes)	Seenghala	Actinopterygii	Siluriformes	Bagridae
Rasbora daniconius		Actinopterygii	Cypriniformes	Cyprinidae
Channa punctatus (Bleeker)	Girai	Actinopterygii	Ophiocephaliformes	Channidae
Channa striatus (Bleeker)	Shaul	Actinopterygii	Ophiocephaliformes	Channidae
Channa marulius (Ham.)	Saur	Actinopterygii	Ophiocephaliformes	Channidae
Gadusia chapra	Suiya	Actinopterygii	Clupeiformes	Clupeidae
Notopterus notopterus (Ham.)	Patra	Actinopterygii	Clupeiformes	Clupeidae
Cirrhinus reba (Ham.)	Raiya	Actinopterygii	Cypriniformes	Cyprinidae
Puntius sarana (Ham.)	Puthia	Actinopterygii	Cypriniformes	Cyprinidae
Puntius sophore (Ham.)	Bhoor	Actinopterygii	Cypriniformes	Cyprinidae
Labeo calbasu (Ham.)	Karaunch	Actinopterygii	Cypriniformes	Cyprinidae
Labeo bata (Ham.)	Bata	Actinopterygii	Cypriniformes	Cyprinidae
Hypophthalmichthys nobilis		Actinopterygii	Cypriniformes	Cyprinidae
Glossogobius giuris (Ham.)	Gobi	Actinopterygii	Perciformes	Gobiidae
Xenentodon cancila (Ham.)	Kauwa	Actinopterygii	Beloniformes	Belonidae
Chanda nama (Ham.)	Gurda	Actinopterygii	Perciformes	Centropomidae
Oreochromis mossambicus		Actinopterygii	Perciformes	Cichlidae
Heteropneustes fossilis (Bloch)	Singhi	Actinopterygii	Siluriformes	Siliridae
Mastacembalus armatus (Lacepede)	Baam	Actinopterygii	Mastacembeleformes	Mastacembelidae
Mystus cavasius		Actinopterygii	Siluriformes	Bagridae
Salmophasia bacaila		Actinopterygii	Cypriniformes	Cyprinidae
Oxygaster spp. (Ham.)	Chelwa	Actinopterygii	Cypriniformes	Cyprinidae
Labeo dyocheilus		Actinopterygii	Cypriniformes	Cyprinidae

Table 5: Diversity indices calculated based on fish catch data in Nanaksagar reservoir

Biodiversity parameters	September	October	November	December	January	February	March
Taxa_S	25	28	27	30	30	30	30
Individuals	344	492	567	655	674	574	570
Dominance_D	0.1708	0.1751	0.173	0.1543	0.1439	0.178	0.1046
Shannon_H	2.161	2.118	2.119	2.259	2.337	2.184	2.612
Simpson_1-D	0.8292	0.8249	0.827	0.8457	0.8561	0.822	0.8954
Evennes_e H/S	0.4338	0.3616	0.3783	0.3829	0.4139	0.3552	0.5453
Menhinick's	1.065	1.028	0.9183	0.9689	0.9569	1.034	1.037
Margalef's	3.253	3.549	3.312	3.701	3.685	3.778	3.782

Table 6: Correlation between physicochemical parameter and fish production at the selected sites of Nanak Sagar reservoir during the study period

Parameters	Temp.	Transparency	EC	TDS	pH	DO	CO_2	Alkalinity	Phosphate	Nitrate	Fish production
Temp.	1										
Transparency	-0.7527	1									
EC	-0.1109	-0.1662	1								
TDS	0.55915	-0.6252	-0.37150	1							
pH	-0.8189	0.6992	-0.20032	-0.5319	1						
DO	-0.6418	0.2236	0.500721	-0.6923	0.4666	1					
CO_2	0.56024	-0.2124	-0.38328	0.6728	-0.3906	-0.9716	1				
Alkalinity	-0.6746	0.2590	0.404944	-0.6426	0.5507	0.9796	-0.9548	1			
Phosphate	0.67736	-0.3285	-0.69616	0.4842	-0.3077	-0.7152	0.6037	-0.7097	1		
Nitrate	0.71271	-0.3098	-0.64830	0.5662	-0.3746	-0.8711	0.7944	-0.8670	0.9618	1	
Fish production	-0.7719	0.4791	0.185419	-0.6662	0.7988	0.8496	-0.8080	0.92221	-0.6216	-0.7526	1

Labeo rohita

Labeo gonius

Notopterus notopterus

Xenentodon cancila

Catla catla

Cirrhinus mrigala

Ctenopharyngodon idella

Cyprinus carpio

Labeo bata

Labeo dyocheilus

Oxygaster spp.

Gadusia chapra

Heteropneustes fossilis

Labeo calbasu

Chanda nama

Mystus seenghala

Mastacembalus armatus

Channa punctatus

Mystus cavasius

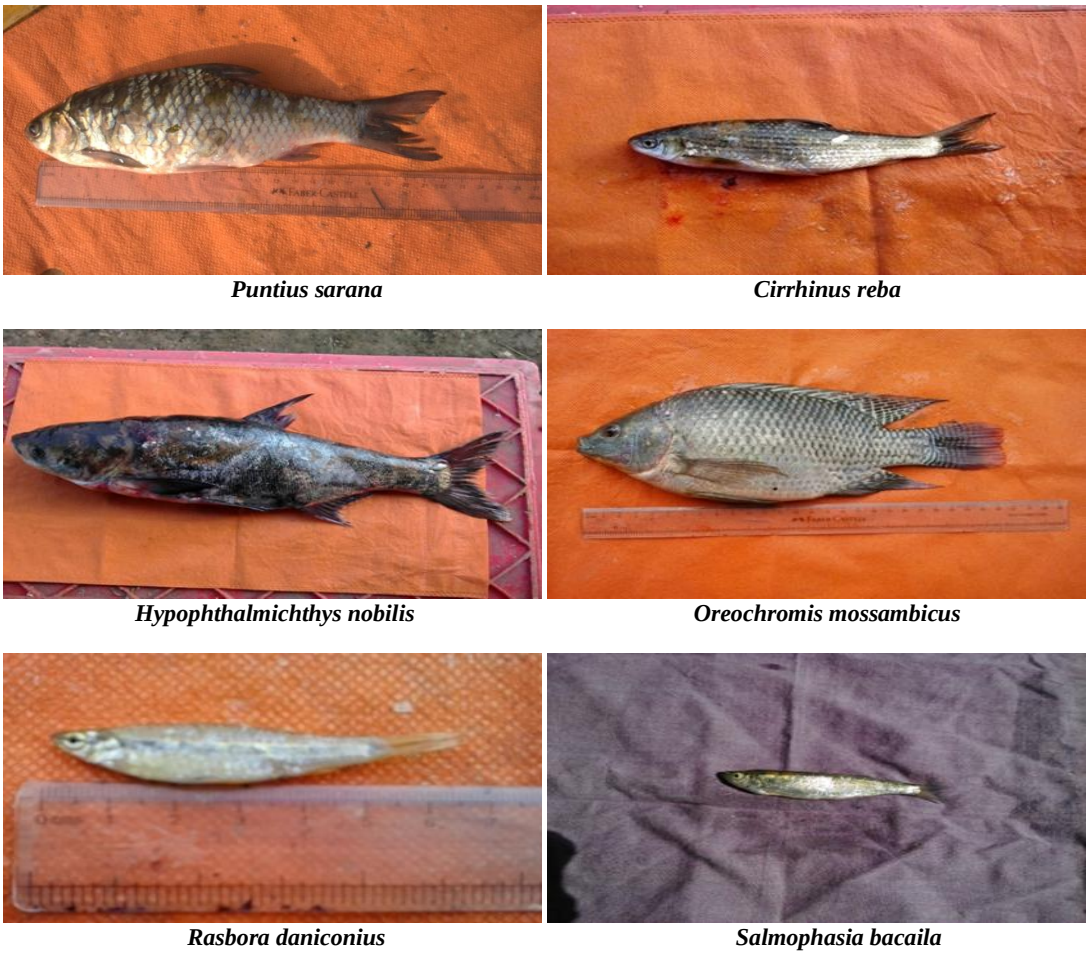
Wallago attu

Glossogobius giuris

Channa marulius

Channa striatus

Puntius sophore



Puntius sarana | *Cirrhinus reba*

Hypophthalmichthys nobilis | *Oreochromis mossambicus*

Rasbora daniconius | *Salmophasia bacaila*

Plate 1: Fish photos

4. Conclusion

The present study indicates that the water quality of the selected reservoir is within normal condition but the fish production level is not so satisfactory due to imbalanced trophic structure. The fish production was low due to several problems such as over population of weed fishes occupying 56.9% of the total catch and preponderance of Cat fishes/ Carnivorous fishes (9.92%), decrease in water depth due to excessive sedimentation, excessive macrophytic vegetation, poor stocking of commercially important fishes, illegal fishing during breeding period, poaching etc.

The present study provides information on the current status of water quality and biodiversity of Nanaksagar reservoir. The present fish production from the reservoir could be increased through adoption of culture based fisheries.

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