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Present status and diversity of ichthyofauna at five selected sites of the Gomti River, Lucknow (India)

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Abstract
Anthropogenic activities affect aquatic habitats leading to loss of many species as well as bring changes in the species composition of some regions. Therefore, ichthyofaunal diversity studies are essential for sustainable management. An exploratory study regarding the ichthyofauna of the river Gomti at Lucknow has been done which is presented in this paper**.** In total 61 icthyospecies belonging to 18 families and 8 orders were caught. *Hypophthalmichthys molitrix, Cyprinus carpio, Clarias gariepinus* and *Ctenopharyngodon idella* were the exotic fish species in the Gomti River**.** The study revealed that there were noteworthy variations found in the ichthyofaunal diversity indices among five different selected sampling sites. Cypriniformes emerged out as the dominant order at all the selected sites. The present study shows that in spite of high pollution level, numbers of fishes were found satisfactory in most of the selected sites of this river.

Keywords: River Gomti, fish, Ichthyofaunal diversity, abundance, richness

1. Introduction
The ichthyofauna in river is changing swiftly and is in constant danger due to degradation of habitat, contamination, over-exploitation and other human activities. Introduction of exotic species is also a major factor which may have drastic effect on native fish species. River are the most prone to be disturbed by anthropogenic activities. These activities cause modification in habitat qualities of large rivers and other water bodies. This in turn affects the aquatic organisms and a large number of species become threatened or even get extinct. Fishes are considered as good indicator of the health of the river ecosystems as many workers have suggested regarding the use of fishes as bio indicators such as [1-9]. Some other workers have emphasized that fishes are susceptible to a various stressors and reflect their negative effect [10]. It is reported that changes occurred naturally or human induced in the environment where fishes lives made them to response accordingly [11]. Local environmental factors of any water body play a crucial role in sustainability of ichthyofauna of that particular place [12].

One of the tributary of the river Ganga is the Gomti, which flows about 12 km through Lucknow city, capital of Uttar Pradesh. The river Gomti is the main source of water for people of Lucknow. The river starts from a natural lake 'Fulhar Jheel' in the forested region near to Pilibhit town in Uttar Pradesh, around 50 km south of the Himalayan foothills. The river moving through the central and eastern segment of Uttar Pradesh navigates an add up to division of around 730 km before finally merging with the Ganga river close to Varanasi. Sai, Reth, Luni, Kalyani, Kathna and Sarayan rivers are the tributaries of the Gomti river [13]. The river receives unprocessed sewage of 26 drains in the Lucknow area. Earlier to Lucknow, Gomti also receives wastes from industries of Sitapur. It is well known now that Gomti River is highly polluted. There are various reports that Gomti River receives various types of pollutants such as effluent from sugar factories and distilleries, fertilizers, pesticides, medical wastes, domestic waste water and sewage. Industrial waste such as vegetable oil mud, shale slag, waste organic solvents, milk waste products and other industrial waste are also dumped in the river [14-17]. Increasing population of Lucknow is further multiplying the problem. [18] noticed that anthropogenic factors such as habitat alteration, sewage pollution are some of the reasons due to which even mass mortality of fishes have been reported in the river Gomti. As per the report of Uttar Pradesh Pollution Control Board (UPPCB), flow of Gomti has much decreased and because of this biomass on the waterway has increased. Freshwater fishes are the most diverse and also highly threatened of all vertebrate groups [19].

Exotic fishes, introduced for different purposes or came accidently in our river system [20] in turn are affecting native fish species. Apart from pollution exotic fishes are also supposed to be potential threat for the biodiversity of this river. This is need of the hour to maintain the record of all fish diversity**.** Moreover, update a record of already identified species is also required [21]. This will help in correct identification and conservation of fresh water fishes of river Gomti. Establishing precise fish assemblage record is a necessary move for freshwater biodiversity conservation.

Various workers studied ichthyofauna of different water bodies yet there is dependably scope for upgrading of information. Aside from this, the detailed study of ichthyofauna of the Gomti river is deficient. So in order to evaluate freshwater fishes of the Gomti river at Lucknow this study has been under taken.

2. Material and methods

A widespread survey work has been carried out regarding the ichthyofaunal availability in the river Gomati during January, 2015 to June, 2016. For proper records, fish species were collected from different sites (Pipe wala pul, Kuriya ghat, Pakka Pul, Saheed smarak and Gomti barrage) (Table 1) of river Gomti. Sampling at every station was made at month to month interims. Sampling was completed on 100–200-m extends of the river at each site. A variety of fishing gear such as cast, gill and drag nets were used for this purpose. Total numbers of each species were recorded for each month and from every site. Many fishes are released back to water after identification and counting their numbers at the sampling sites. The remaining specimens were fixed in 10% formalin solution in the field and later preserved in 5% formalin in the laboratory. Fresh or preserved specimens of fishes were identified. To find out the species status all taxonomic parameters such as the morphology, morphometry, meristic counts, scale number and colour shading were examined using keys of [22-25] and for valid scientific name website (FishBase) were also referred. IUCN website was used to assess conservation status of each fish species. In addition, regular visit to the local fish markets and interaction with the local fishermen's communities data were generated.

Table 1: Details of study sites

S. No	Sampling sites		Latitude and longitude of the sampling sites
1	Pipe wala pul	G1	26.8871°N 80.9006°E
2	Kuriya ghat	G2	26.8741°N 80.9119°E
3	Pakka pul	G3	26.8727°N 80.9162°E
4	Saheed smarak	G4	26.8634°N 80.9286°E
5	Gomti barrage	G5	26.8555°N 80.9694°E

3. Data analysis

Knowledge about ecosystem and its functions could help one to have a suitable environment management [26]. There are number of methods to study ecological unit. Diversity indices provide important information about rarity and commonness of species in a community. No single index able to conclude status of biodiversity therefore a combination of some diversity indices were used to calculate the multiplicity of the assemblage and for the statistical comparison of the diversity at five different sites of the study area viz.

(A.) Relative abundance (RA) = number of samples of particular species x 100/Total number of samples.

(B.) Shannon Weiner diversity index [27],

Formula: $H' = \Sigma Pi \times \log Pi$, Where, $Pi = ni/N$

Where, ni is the quantity of individuals of each species in the sample, N is the total number of individuals of all species in the sample.

(C.) Simpson's dominance index [28],

Formula: $D = \Sigma ni\ (ni-1)/ N\ (N-1)$

Where, ni is the total number of individuals of a particular species and N is the total number of individuals of all species.

(a.) Simpson's Index of Diversity= (1- D)

(b.) Simpson's Reciprocal Index= (1 / D)

(D.) Evenness Index [29]. Formula: e = H / In S,

Where, e=Evenness Index, H = Shannon – Wiener diversity index, S = total number of species in the sample.

(E.) Similarity index (Sj), [30], Formula: Sj = j/(x + y - j)

Where, Sj is the similarity between any two regions X and Y, j the number of species common to both the regions X and Y, x the total number of species in region X and y total number of species in region Y

(F.) Origin index (OI), [31], Formula: Origin Index= Number of non-native species/ Number of native species.

Above index was modified as |1-X|, Where, X is the estimation of the index (number of non-native species/ number of native species).

(G.) Measurement of species richness, Margalef's index, [32]

Formula: $d = (S - 1)/\ln N$

Where, d = Margalef's diversity index, S = total number of species, N = total number of individuals in the sample, ln = natural logarithm**.**

(H.) Species Diversity= No. of Species x 100/√ Total Number of individuals.

Detailed analysis and graphical presentation of data were calculated using Microsoft Excel (version 2007). Biodiversity indices were determined using PAST (Paleontological Statistics) and SPSS (Statistical Analysis for Social Sciences, version 16.0) software.

4. Results and discussion

In exploratory surveys, 61 fish species in total were yielded and identified of freshwater fishes classified to 41 genera, 18 families and 8 orders. Four were exotic fish species (Table 2). [33] Also worked on fish biodiversity of river Gomti, total 70 species belonging to nine order, twenty one families and forty two genera were recorded in his study. [34] Reported total 56 fish species belonging to 20 families and 42 genera. [35], in his study, reported 62 species belonging to 47 genera, 21 families and seven orders from the river Gomti. [34] Reported 4 exotic species while [35] documented five exotic species and [33] noticed 2 exotic species but not clearly mentioned them.

Our result is close to the findings of [34]. The total number of species (61) found in the present study are in accordance with [35] but considerably higher than the number of species (56) reported from river Gomti [34] and lower than finding (70) of [33] which might be attributed to only particularly sites of river

Gomti was taken for this study but in earlier study of [33] their collections were also done from canals, ponds and tanks of outskirts areas and in adjoining districts of Lucknow. In present study and all the above cited studies Cypriniformes was the major order followed by Siluriformes.

Table 2: Relative abundance of ichthyospecies at different sampling sites of river Gomti, name of their order, family, scientific name, common name, fin formula, IUCN threat status (2016) and economic importance.

Order	family	SN	Icthyospecies	Common name	Fin formula	Site G1	Site G2	Site G3	Site G4	Site G5	IUCN status 2016	Economic imp.
Beloniformes	Belonidae	1	*Xenentodon cancila* (Hamilton, 1822)	Kauwa	D 15-18; A 16-18; P 11; V 6	3.45	2.36	1.60	3.64	3.32	LC	FF, OF
Clupeiformes	Clupeidae	2	*Gudusia chapra* (Hamilton, 1822)	Suiya	D iv 11-13; A (ii) iii 19-22; Pi 12-13; V i 7	1.79	1.18	01.60	1.52	1.81	LC	FF
	Engraulidae	3	*Setipinna phasa* (Hamilton, 1822)	Phasia	D i 14-15; A iii 66-78; P i 14; V i 6	0.96	0.71	0.31	0.79	1.27	LC	FF
Cypriniformes	Cyprinidae	4	*Amblypharyngodon mola* (Hamilton, 1807)	Moa	D ii- iii 7; A ii-iii 5-6; P i 13-15; V i 8	3.55	3.64	1.24	2.17	0.70	LC	FF
		5	*Aspidoparia morar* (Hamilton,1822)	Pirohia	D ii-iii 7-8; A ii 8-10; P i 14; V i 7	0.35	0.47	0	0.54	0.57	LC	OF, FF
		6	*Gibelion catla* (Hamilton, 1822)	Katla	D iii-iv 14-16; A iii 5; P i 20; V i 8	0.49	5.42	1.11	1.10	2.03	LC	Cu, Co
		7	*Chela laubuca* (Hamilton, 1822)	Dendula	D ii 8-10; A ii 17-22; P i 8-11; V i 6	2.11	1.74	1.68	1.57	0.90	LC	OF
		8	*Cirrhinus mrigala* (Hamilton 1822)	Mrigal	D iii-iv 12-13; A iii 5; P i 17; V i 8	2.85	0.27	8.30	6.95	9.45	LC	Co, Cu
		9	*Cirrhinus reba* (Hamilton, 1822)	Rewah	D ii-iii 8; A iii 5; P i 15; V i 8	4	2.19	1.27	1.70	0.57	LC	Co, Cu
		10	*Ctenopharyngodon idella* * (Valenciennes,1844)	Grass carp	D.3/7, P_1 1/17, $P_2$1/8,A.3/7-8	0.02	0.38	0.15	0	0.30	NE	Co, Cu
		11	*Cyprinus carpio** (Linnaeus, 1758)	Common carp	D III-IV (V) 15-22, A III-IV 5-6	0.42	1.52	1.56	0.45	1.09	VU	Co, Cu
		12	*Hypophthalmichthys molitrix* * (Valenciennes, 1844)	Silver carp	D.3/7, P_1 1/17, $P_2$1/7,A.2-3/12-14	0.14	0	0.31	0	0.15	NT	Co, Cu
		13	*Labeo angra* (Hamilton, 1822)	Rewa	D ii-iii 10; A ii 5; P i 15; V i 8	0.22	0	0.18	0	0.32	LC	FF
		14	*Labeo bata* (Hamilton, 1822)	Bata, bhagan	D ii-iv 9-10; A ii-iii 5; P i 15-17; V i 8	3.86	1.49	1.42	1.47	1.01	LC	Co, Cu
		15	*Labeo calbasu* (Hamilton, 1822)	Kalabenise	D iii-iv 13-16; A ii-iii 5; P i 16-18; V i 8	2.53	2.34	3.23	1.36	3.32	LC	FF
		16	*Labeo gonius* (Hamilton, 1822)	Bata	D ii-iii 13-16; A ii 5-6; P i 16; V i 8	0.79	0.29	0.62	0.57	0.35	LC	FF
		17	*Labeo pangusia* (Hamilton, 1822)	Rewa	D ii-iii 10-11; a ii 5; P i 14-15; V i 8	0.15	0.11	0.16	0.11	0.03	NT	FF
		18	*Labeo rohita* (Hamilton, 1822)	Rohu	D iii-iv 12-14; A ii-iii 5; P i 16-18; V i 8	2.45	3.95	3.39	3.30	2.01	LC	FF
		19	*Osteobrama cotio* (Hamilton, 1822)	Chela	D. 11 (2/8); P_1.15; P_2 9-10,A.33-36(3/30-33)	0.28	0.47	0.20	0.35	0.49	LC	FF, OF
		20	*Pethia ticto* (Hamilton, 1822)	Pothia	D iii-iv 8; A ii-iii 5; P i 12-14; V i 8D ii 8; A	2.76	2.41	6.34	6.75	7.64	LC	OF, Bait, FF
		21	*Puntius chola* (Hamilton, 1822)	Siddhari	D iii 8; A ii 5; P i 14; V i 8	1.53	2.99	1.76	3.55	3.92	LC	OF
		22	*Pethia conchonius* (Hamilton, 1822)	Pothi	D iii 7-8; A ii-iii 5; P i 18; V i 8	1.59	3.06	3.32	3.55	4.10	LC	FF, OF
		23	*Puntius sophore* (Hamilton, 1822)	Sidhari,Pothi	D iii-iv 8-9; A iii 5; P i 14-16; V i 8	7.50	04.44	5.18	4.57	13.17	LC	OF,B,MV
		24	*Systosoma sarana* (Hamilton, 1822)	Darhi	D iii-iv 8; A iii 5; P i 14-16; V i 8	0.40	0	0.47	0	0	LC	FF

		25	*Salmostoma bacaila* (Hamilton, 1822)	Chelhava	D ii-iii 7; A iii 10-13; P i 11-12; V i 8	2.45	17.78	14.67	9.01	3.92	LC	FF, OF
Synbranchiformes	Mastacembelidae	26	*Macrognathus pancalus* (Hamilton, 1822)	Bami, turi	D. 24-26/35-37, P1. 19-20, A. III/ 37-40	0.88	0.31	0.96	0.77	0.94	LC	FF
		27	*Mastacembelus armatus* (Lacepède,1800)	Baam, gomi	D.37-38/78-84; P_1.25-26,P_2.absent;A. III/77-85	0.85	0.89	0.93	0.78	0.77	LC	FF
	Synbranchidae	28	*Monopterus cuchia* (Hamilton, 1822)	Anhaya Baam	D. rudimentry P_1 P_2 A & C absent	0.14	0.02	0.15	0	0.23	LC	FF
Ophiocephaliformes	Ophiocephalidae	29	*Channa marulius* (Hamilton,1822)	Pumuri	D 45-55; A 28-36; P 16-18; V 6	0.91	0.38	0.31	0.89	1.17	LC	Co, Cu
		30	*Channa orientalis* (Bloch & schneider 1801)	Chainga	D 32-37; A 20-23; P 14-15; V 6	0.32	0.27	0	0.35	0.35	NE	Co
		31	*Channa punctata* (Bloch, 1793)	Girahi	D 28-33; A 20-23; P 15-18; V 6	0.98	1.43	1.40	1.01	1.12	LC	Co, Cu
		32	*Channa striatus* (Bloch, 1793)	Souri	D. 37-46; A 23-29; P 15-17; V 6	0.32	0.20	0	0.05	0	LC	Co, Cu
	Notopteridae	33	*Notopterus chitala* (Hamilton, 1822)	Mohi, Patra,	D.7-8;P_1.15-16;P_2.6; A. 115-120	1.22	1	1.47	0.86	0.80	NT	MV
		34	*Notopterus notopterus* (Pallas, 1769)	Fooli	D.7-8;P_1.15-17;P_2.5-6;A.99-104	3.57	2.16	1.68	2.04	1.78	LC	FF, OF,GF
Perciformes	Anabantidae	35	*Anabas testudineus* (Das,1966)	Kawai	D XVI - XVIII 8-10; 4A VIII - XI 9-11; P_1.13-14; V I 5	0.30	0.42	0.44	0.30	0.30	DD	FF
		36	*Nandus nandus* (Hamilton, 1822)	Nandus	D XII - XIV 11-13; A III 7-9; P 15; V I 5	0.87	0.85	1.04	1.01	0.94	LC	FF
		37	*Trichogaster fasciatus* (Bloch & Schneider,1801)	Khosti	D XV - XVII 9-14; A XV - XVIII 14-19; P 9-10	2.21	6.71	7.33	6.72	4.62	LC	OF
		38	*Trichogaster lalia* (Hamilton, 1822)	Khosti	D XV - XVII 7-10; A XVII - XVIII 13-17; P 10	1.08	0.51	1.32	1.07	1.46	LC	FF, Co, OF
	Ambassidae	39	*Chanda nama* (Hamilton, 1822)	Chanari	D VII + I 15-17; A III 15-17; P ii 11-12; V I 5	0.84	1.32	0	0.00	1.51	LC	Ff
		40	*Parambassis ranga* (Hamilton, 1822)	Chanar	D VII+I 11-14; A III 13-15; P i 11-12; V I 5	1.21	2.43	1.09	0.91	1.31	LC	Little Food Value
	Badidae	41	*Badis badis* (Hamilton,1822)	Badis	D XVI - XVIII 7-10; A III 6-8; P 12; V I 5	0	0.27	0.10	0.14	0.25	LC	FF, OF
Siluriformes	Bagridae	42	*Aorichthys aor* (Hamilton, 1822)	Daryai-Tengara	D I 7; A iii-iv 8-10; PI 9-10; V i 5; C 17	1.08	0.25	0.28	0.46	0.05	LC	GF, Co
		43	*Aorichthys seenghala* (Sykes, 1839)	Tengra	D I 7; A iii 8-9; P I 9; V i 5; C 19-21	0.31	0.31	0.46	0.80	0.32	LC	FF
		44	*Rita rita* (Hamilton, 1822)	Ritha	D I 6; A ii 10-11; P I 10; V i 6-7	1.21	0.20	1.42	0.91	0.87	LC	FF
		45	*Mystus cavasius* (Hamilton, 1822)	Daryai-Tengar	D I 7; A iv 7-9; P I 8; V i 5	1.08	1.07	0.75	0.65	0.35	LC	Co
		46	*Mystus tengara* (Hamilton,1822)	Tengara	D I 7; A ii-iii 9-10; P I 8; V i 5	0.83	1	0.85	1.01	0.97	LC	Ff, Of
		47	*Mystus vitatus* (Bloch, 1794)	Tengra	D I 7; A ii-iii 7-9; P I 9; V i 5	1.21	1.05	0.96	0.88	0.82	LC	FF, OF
		48	*Mystus bleekeri* (Day, 1877)	Tengrea	D I 7-8; A iii 6-7; P I 9-10; V i 5	0.23	0.18	0.20	0.01	0	LC	FF
	Clariidae	49	*Clarias batrachus* (Linnaeus, 1758)	Mangur	D 70-76; A 45-58; P I 8; V i 5	0.83	1.67	0.68	0.89	0.59	LC	OF, Cu
		50	*Clarias gariepinus** (Burchell, 1822)	Thai magur	D. 61-80, P_1 1/9-10, P_2 6 A 45-65	0	0.29	0.23	0	0.35	LC	FF
	Pangasiidae	51	*Pangasius pangasius* (Hamilton,1822)	pungas	D I 6-7; A iv-v 26-29; P I 12-13; Vi 5	0.51	0.40	0	0.51	0.49	LC	GF
	Schilbeidae	52	Ailia coila (Hamilton, 1822)	Kajoli	A 58-75; P I 14-16; Vi 5	1.36	2.19	1.40	1.23	0.64	NT	FF
		53	*Clupisoma garua* (Hamilton, 1822)	Karahi	D.1/7;P_1.1/11;P_2.6; A.3/27-30	4.99	1.99	3.24	3.55	1.62	LC	FF

		54	*Eutropiichthys vacha* (Gunther, 1868)	Banjhoo	D_1.7;$P_{1.}$14;$P_{1.}$14;$P_{2.}$5;A.49;C.19	10.45	3.30	2.51	7.86	5.78	LC	FF
	Heteropneustide	55	*Heteropneustes fossilis* (Bloch, 1794)	Singhi	D 6-7; A 60-70; P I 7; V i 5	2.41	1	0.21	1.92	1.83	LC	MV, FF
	Sisoridae	56	*Ompok bimaculatus* (Bloch, 1794)	Jalkapoor	D 4; A ii-iii 57-58; P I 12-14; V i 7-8	4.70	1.99	4.68	2.15	3.30	NT	FF
		57	*Ompok pabda* (Hamilton, 1822)	Pabda	D 4-5; A ii 48-54; P I 11-13; V i 6-7	0.35	0	0.37	0.30	0	NT	FF, OF
		58	*Ompok pabo* (Hamilton, 1822)	Pabo, Pahboh	D 5; A iii 63-68; P I 14; V i 8-9	0.42	0.87	0.78	0.19	0.49	NT	FF
		59	*Wallago attu* (Bloch & Schneider,1801)	Padhani	D.5;$P_{1.}$1/13-14;$P_{2.}$10;A.85-89	1.40	1.32	1.47	1.32	0.90	NT	FF
		60	*Bagarius bagarius* (Hamilton, 1822)	gonch	D I 7; A iii 9-12; P I 9-12; V i 5	4.14	2.36	1.24	3.30	0.65	NT	FF,GF,OF
Tetraodontiformes	Tetraodontidae	61	*Tetraodon cutcutia* (Hamilton, 1822)	Galphulani	D 10-11; A 10; P 18-21	0.16	0.18	0	0.11	0	LC	OF

VU vulnerable, EN endangered, NT near threatened, LC least concern, NE not evaluated
FF Food Fish, OF ornamental fish, GF Game fish, MV medicinal value, CU Cultivable fish, CO Commercial fish, * Exotic fish species

Table 3: Site wise diversity indices of finfish in the Gomti River

Sampling Sites	Total species	Simpson's Index D	Simpson's Index of Diversity (1-D)	Simpson's Reciprocal Index (1/D)	Species Diversity	Margalef Richness Index	Origin index	Shannon Index H	Evenness
G1	8092	0.038	0.962	26.54	65.58	6.445	0.946	3.605	0.884
G2	4483	0.054	0.946	18.38	85.13	6.66	0.925	3.448	0.853
G3	6136	0.052	0.948	19.22	70.24	6.191	0.922	3.409	0.851
G4	9727	0.042	0.958	23.71	54.76	5.772	0.941	3.483	0.873
G5	5970	0.050	0.950	20.05	69.89	6.326	0.981	3.431	0.852

4.1. Relative Abundance
Relative abundance of fishes of the river Gomti showed dominancy of small sized indigenous species (Table 2) such as *S. basilica* (17.78%) at site G2, *P. sophore* (13.17) at site G5, *T. fasciatus* (6.72) at site G4 (Shaheed smarak), *and P. ticto* (6.34) at G3 (Kuriya ghat), *P. conchonius* (4.10) at site G5 (Gomti barrage). Some IUCN red data listed fish species under near threatened category namely species *B. bagarius* (4.14) and *O. bimaculatus* (4.70) both were comparatively abundant at site G1 (Pipe wala pul).

4.2. Shannon-Weiner index
The Shannon-Weiner fish diversity index of all the sites was ranged from 3.409 to 3.605. In this study maximum fish diversity index was recorded in sites G1 (Pipe wala pul) (H=3.605) and minimum in site G3 (Pakka pul) (H=3.409) (Table 3). Shannon –wiener index shows that diversity of the fishes is good, the value of *H* usually falls between the values 1.5 and 3.5, and it not often exceeds the value 4.5 [36]. Shannon diversity index among the stations were significantly differently. Shannon-Weaver diversity index ranged from 3.0-4.5 indicates suitable conditions of water body for Ichthyofaunal diversity [37]. In the present study diversity index was ranged from 3.409 to 3.605. The result indicates that river Gomti is still favourable to ichthyofauna of studied regions. Although the fish community indices across the river were less if compared to other larger rivers on the earth.

4.3. Simpson Index (D)
The Simpson diversity (dominance) indices in different sites were varied from 0.038 to 0.054
(Table 3) and had a contrary relationship with evenness and diversity. The highest were recorded at site G2 (Kuriya ghat) and lowest at site G1 (Pipe wala pul). In general, the value of D ranges between 0 and 1, with this index 0 stands for infinite diversity and 1, no diversity. That is, the greater the value of D, the lesser the diversity. The smallest value at site G1 indicated that this site more divers in comparison to other sites. Making it simpler, we calculated the value of (1-D), greater the value of (1-D) the more divers is the site (Table 3).

4.4. Evenness
Evenness is a quantification of the relative abundance of the different species building up the possessions of an area. The distributions of individuals or species evenness (E) in the sites were uneven varied from 0.851 to 0.884 (Table 3). Generally, E values ranging between 1 and 0, fish populations nearer to 1 the more even the structure of community. The highest evenness was found at sampling site G1 (Pipe wala pul), while the lowest at site G3 (Pakka pul).

4.5. Jaccard similarity index
This index presumes that if the calculated value is 1, there is entire similarity of species between two sites, and there is no similarity, if the value is 0. In this index, values range from 0 to 1 with the higher value signifying greater similarity. The similarity index between pair wise comparisons of sites ranged from 0.81 to 0.91. The highest similarity was found between sites G1 (Pipe wala pul) and G4 (Saheed smarak) followed by G2G4 while G2G3 less similar to others. Jaccard similarity index was significant across the five sites, indicating that fish species compositions were not similar among sites. There is no direct correlation have been found among the distance between sites and Jaccard similarity. In the present study the Jaccard's similarity index in the sites of areas showed more similarity across the sites regardless if they were in distance wise close to each other or away. Similarity in species composition across the study sites is

shown as a dendrogram in Fig. 1, attained from the JI coefficients of similarity using the average linkage method.

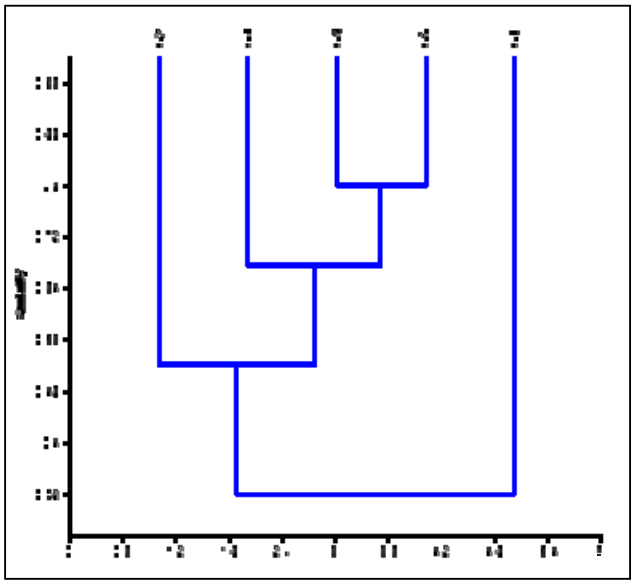

Fig 1: Dendrogram showing similarity in composition of fish across five sampling sites of Gomti River based on Jaccard index.

4.6. Origin Index

The more native species are present on the site in comparison to non-native species, the lower the ratio. When there are no non-native species on the site. The ratio is 0, thus the OI index always have a tendency to be 1. In reverse, the greater the ratio, the fewer native species are there on the site in comparison to non-native species. The highest value (0.981) of origin index was recorded at site G5 (Gomti barrage) while low at sites G3 (0.922) (Table 3). The high value at site G1 showed comparatively less abundance of exotic species. In general, the high value of Origin index shows that fish assemblages included less non-native species in comparison with native species [38]. This shows more exotic species was thriving in G3 (Pakka pul) site then other sites. In this study, lower ratio of origin index suggesting that river Gomti is not very much affected by species introduction but occurrence of exotic species should be treated as threat to the ecological integrity of river Gomti.

4.7. Margelef Index

This index is used for comparative assessment of the sites. It depends upon the difference in species number and there is no preset maximum value for this index [39]. The quantity of species per test is a measure of abundance. The more species present in a site, the "wealthier" the site. The Margelef index of species richness values shown high at site- G2 (6.66), moderate at sites- G1 (6.445), G5 (6.326), G3 (6.191) and low at site G4 (5.772). These values signifies good connection with overall species richness across the sites and comparatively highest diversity was found at G2 (Kuriya ghat) site. This indicates more favourable conditions for fishes at this site to support the fish diversity.

4.8. Assessment of fish diversity

In present study of river Gomti, the total species contribution of food fishes was 46, 19 species were used as aquarium fishes and 4 species were potential game fishes. Among the food fishes, 14 species were of high commercial value whereas 11 species were assessed as potential cultivable species (Table 2). Pretty much comparable findings were reported by [34] in his study out of 56 species 20 species were potential aquarium fishes, 49 species were potential food fishes and four species were under potential sport fishes. For this present study, family-wise abundance of fishes is shown in Fig 2, order-wise fish composition detail shown in Fig 3 also in Fig 4, a pie diagram showing the composition of Gomti ichthyofauna as per the food value.

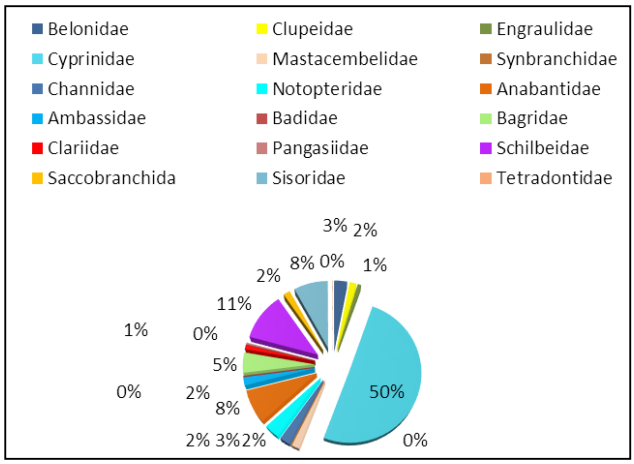

Fig 2: Family wise fish composition details of the Gomti River

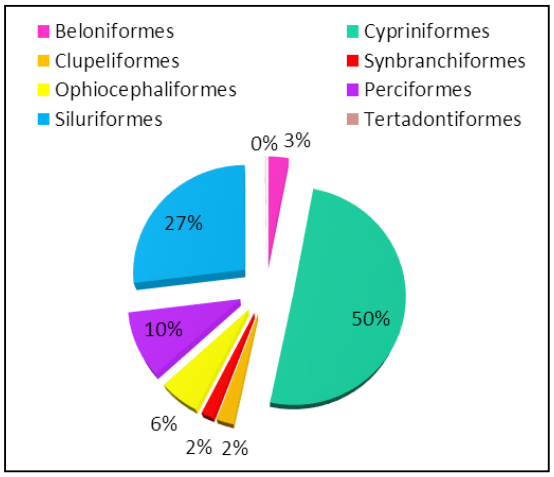

Fig 3: Order-wise fish composition detail in the Gomti River, Lucknow

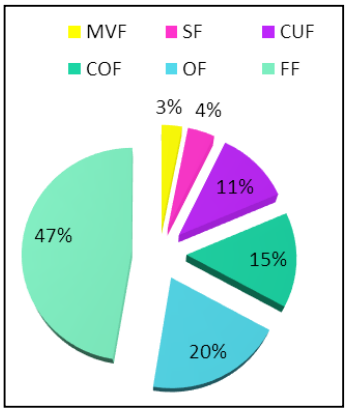

Fig 4: Composition of fish species (in %) of Gomti river as per the food value

4.9. Threats

As per IUCN (2016) [40], evaluation of the threat status of 61 fish species of the river Gomti showed nine species as near threatened (NT), 1 species vulnerable, 48 least concern and data on 2 species did not fall under any threat category so we have put them in not evaluated group (Table 2). While following species come under threatened fresh water fishes of India as per NBFGR (2010) [41] *Ompok pabo* (EN), *Badis badis* (VU), *Bagaris* (VU), *Eutropiichthys vacha* (VU), *Heteropneustes fossilis* (VU), *Ompok pabo* (VU), *Pangasius pangasius* (VU), *Puntius chola* (VU), *Puntius sarana* (VU). [33] Reported 6 vulnerable, 2 endangered, 12 indeterminate and 50 not evaluated species as per their self-survey. [34] Reported in his study, out of the 56 species, five species classified in the endangered category and 11 species to the vulnerable (VU) category as per [42].

In present study, as per IUCN 2016 category out of 61 species, about 79% of species are under least concern and 15% near threatened, 1% vulnerable category, 2% data deficient, 3% not evaluated (Fig 5). The site wise analysis of conservation status of fishes of Gomti river showed that site G1 (Pipe wala pul) having more percentage of relative abundance (13.88) of threatened species whereas at site G5 (Gomti Barrage) less relative abundance (6.96) were observed. Over all the maximum fish species least concern were documented during the study periods.

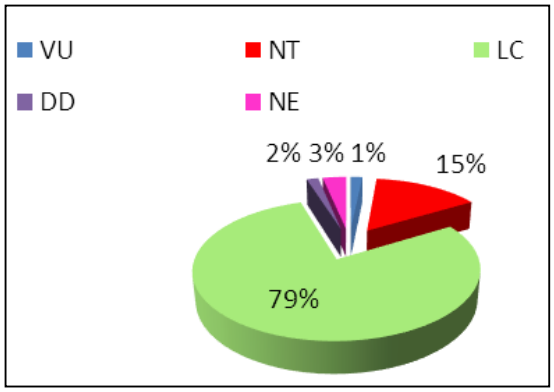

Fig 5: Ecological Status (in %) of fish species in river Gomti, Lucknow, U.P.

The present study revealed that biodiversity indices were divergent across the selected sites. Perhaps, this is because of variation in natural surroundings, presence of different biotic and abiotic ecological components at different sites. Abiotic components contain nourishment availability, elevation, oxygen substance and primary production of green plants [43, 44]. Besides, this might be due to the distinctive level of human interference at different sites.

5. Conclusion

In spite of pollution and habitat degradations Gomti at Lucknow region supports ichthyofaunal diversity. Although due to impact of anthropogenic activities or other factors diversity indices found significantly different across the sites. This study could serve as baseline data in assisting other stations of river for both conservation and management of fisheries resources. There was a plan for linking the Gomti with river Sharda though it was rejected on technical ground [45] but might get passed with an alternate way in coming years as per the necessity. Comparative study could be done after river linking with the base line data for observing the impact of river linking on ichthyofauna. Fisheries are one of the fast emerging sectors and may have much contribution in increase of annual GDP in near future. In order to understand and protect the precious ichthyofaunal diversity, fishermen and ichthyologists together can achieve significant result. Above all, some of the benefits of biodiversity may not be evident now but there is possibility. Keeping this in mind all the existing ichthyofaunal diversity must be conserved, restored and managed.

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