Environmental Health Engineering and Management Journal 2017, 4(3), 169–175
http://ehemj.com
doi 10.15171/EHEM.2017.24
Environmental Health Engineering and Management Journal

Original Article

Catch per unit efforts and impacts of gears on fish abundance in an oxbow lake ecosystem in Eastern India

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Abstract

Background: Oxbow lakes are abundant in indigenous fishes, but they are subject to unsustainable fishing practices, potential overexploitation, and indiscriminate use of fine-meshed fishing gear. To quantify the catch per unit effort (CPUE) and impact of fishing gears on fish abundance, a survey was carried out in an oxbow lake in eastern India.
Methods: The gear-wise CPUE for fish caught in per unit hour of operation was calculated by dividing the total sampling gear catch in biomass, which is the observed value of fish caught by a particular gear, by the total sampling effort hours. A value of $P < 0.05$ was accepted as statistical significance.
Results: Average annual values of the CPUE of triangular push nets, gill nets, long lines, seine nets, drag nets, stationary dip nets, cone-framed cast nets, and line and hook were calculated as 328.34, 4.12, 36.71, 572.92, 3928.57, 237.78, 235.80, and 0.44 grams of fish per hour of operation, respectively. All the 8 different gears exhibited lower CPUE during monsoon and post-monsoon seasons than in the pre-monsoon season. The line and hook was dominant (>71%). Cone-framed cast net hauled the maximum catch in biomass (31.51%), and gill nets contributed the maximum number of fish (64.92%). The lower CPUE values of line and hook, gill net, cone-framed cast net and long lines identified them as the most harmful among all gears.
Conclusion: Indiscriminate use of gear, particularly line and hook, gill nets, cone-framed cast nets, and long lines, demands regulations and preventions concerning such gear to obtain higher fish abundance.
Keywords: Fish abundance, Fishing gears, CPUE, Oxbow lake
Citation: Ghosh D, Biswas JK. Catch per unit efforts and impacts of gears on fish abundance in an oxbow lake ecosystem in Eastern India. Environmental Health Engineering and Management Journal 2017; 4(3): 169–175. doi: 10.15171/EHEM.2017.24.

Article History:
Received: 6 February 2017
Accepted: 7 May 2017
ePublished: 28 May 2017

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Introduction

The oxbow lakes were formed by the Ganga River. It supports rich biodiversity and offers a livelihood and nutritional security, yet its conservation is less studied in India. Fish abundance in oxbow lakes is severely impacted by human activities like over-exploitation and the indiscriminate use of fine-meshed fishing gear, which always forces the development of systematic and appropriate planning for biodiversity conservation and management strategies (1-3). Among the different types of fishing gear studied (4,5), those like gill nets and seine nets exhibit highly destructive effects (6-9) on fish abundance. The catch per unit effort (CPUE) is a measure of stock density, physical and financial productivity, and an indicator of the efficiency of a fishing operation. Varied CPUE means from different aquatic systems across the world have been reported as being 1.5-14.0 kg/d (6); 2.04 to 48.99 kg/unit/d (9); 0.58 kg/ha/hr and 0.08 kg/ha/hr/purse seine (10); 20-310 g/h/gear (11); 0.95-15.25 kg/unit/d (12); 2.6-62.4 kg/fisher/d (13). The average daily catch per fisher has been reported as 1.43 kg with different fishing efforts (no of gear/day): push nets (6.75), gill nets (3), cast nets (8), lift nets (5.25), current nets (3.75), and hook (67) (11). Fishing durations (h/d) of gill nets (6-12), push nets (0.5-2), drag nets (2-4), lift nets (2-6), and hooks (2-5) have also been reported with the highest density of fishers and catches in the monsoon season, and the lowest was reported in the pre-monsoon season (5,14). However, not enough information is available on the estimation and impact of CPUE of different fishing gear on the patterns of native fish species abundance in the oxbow lake of the Nadia district, India in particular. As there is a need to develop systematic and appropriate planning for fish conservation and management strategies for oxbow lakes, the current study aimed to quantify the CPUE and impact of 8 different fishing gears on fish abundance in a tropical oxbow lake ecosystem of the Ganga river basin in eastern India.

Materials and Methods

Study area

The Chhariganga oxbow lake (abandoned, fractioned, and derived from the river Ganga), located in the Nakashipara development block of Nadia district, West Bengal, India, was randomly selected. This lake is situated at 23.5800°N, 88.3500°E, about 90 km away from the Kalyani University campus in Nadia and nearly 40 km away from the Tropic of Cancer towards the north. It is a fresh-water, semi-closed oxbow lake and receives water from the Ganga river during the monsoon season through a narrow channel at the northeast corner of a loop in the river. This lake spreads over an area of 58.28 ha and has an annual average depth of 2.6 m. It also stores rain water. The catchment area of the oxbow lake is nearly 600 ha (Figure 1). Climate changes create three distinct annual seasons in this region: the monsoon or rainy season generally runs from July to October; the jute retting period lies normally during August and September; the post-monsoon or winter season runs from November to February; and the pre-monsoon or dry season runs from March to June. Occasional flooding of the surrounding banks occurs during the monsoon season. The oxbow lake is subjected to all forms of human activities, including jute retting during the monsoon season, agriculture, and fishing. It is the only source of irrigation water for the neighboring agricultural communities.

Fish sampling and analysis

Sample fishing was carried out on several random occasions using the expertise of local fisher folk and different types of gear (triangular push nets, gill nets, long lines, a seine net, a drag net, a stationary dip net, and a cone-framed cast net all with varying mesh sizes, and a line and hook) (1-3), which allowed the sampling of a range of fish sizes and minimized the bias due to specific gears (sample size 24). Each gear was operated for a period of 4 to 24 hours at different sites of the oxbow lake, bringing the total mean efforts per day to 65, 44, 77, and 95 with gear densities of 2565, 5161, 2957, and 10 683, and total sampling gear efforts to 3648, 5200, 3411, and 12 259 during the pre-monsoon, monsoon, and post-monsoon seasons, and the full year, respectively. Fishes were sorted by their numbers and weighed.

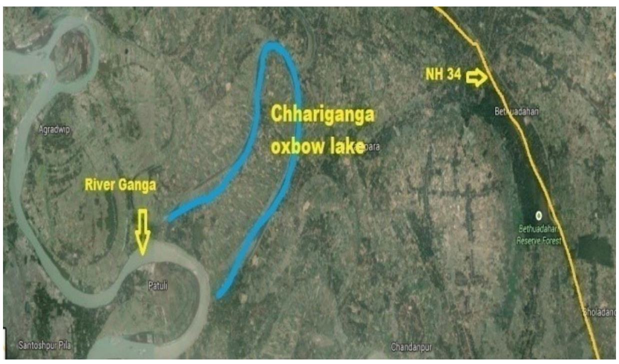

Figure 1. Map showing study area (Modified after being downloaded from google.com on 12-05-2016).

Studies of different fishing gear used in sample fishing

Eight different gears, namely triangular push nets, gill nets, long lines, seine nets, drag nets, stationary dip nets, cone-framed cast nets, and line and hook, which had different dimensions and specifications and varying mesh sizes were considered for fishing in the present study (Table 1). Neither the stationary dip net during the pre-monsoon season (like the triangular push nets or seine nets in Komor, a fish aggregating device (FAD) nor the cone-framed cast net during the monsoon season was seen in operation at the oxbow lake. The drag net was seen to be operated only during the monsoon season. Sample fishing gear densities were based on their appearances observed in the oxbow lake for the three seasons; accordingly, seasonal sampling fishing was randomly performed. Line and hook gear was most dense among all forms, whereas the seine net in Komor was used only once during the year. Eight different fishing gears known to contribute major fish catches in the Chhariganga oxbow lake were studied in detail (Table 1).

Calculation of catch per unit effort

In the current study, gear-wise CPUE for fish caught per unit hour of operation was calculated (1,3) by dividing the total sampling gear catch in biomass (TSGCB) or number (TSGCN), which is the observed value of fish caught by a particular gear, by total sampling effort hours (TSEH). TSEH is calculated as the product of average sampling effort hour of operation of a particular gear per day (SEHPD) and total numbers of such gear used, i.e. sampling gear density (SGD).

$$CPUE\ (g/h\ or\ n/h) = (TSGCB\ or\ TSGCN) \div TSEH$$

Where total sampling effort hours (TSEH)=SEHPD (sampling effort hours/day/gear) x SGD (sampling gear density), g = gram, n = number, h = hour.

Calculation of catch per gear effort

Similarly, the gear-wise catch per gear effort (CPGE) for fish caught per unit effort (or attempt or operation) was calculated [1; 3] by dividing total sampling gear catch (TSGCB or TSGCN) by the total sampling gear effort (TSGE). TSGE was calculated as the product of putting an average sampling effort per day (SEPD) of a particular gear and total numbers of such gear used, i.e. SGD.

$$CPGE\ (g/e\ or\ n/e) = (TSGCB\ or\ TSGCN) \div TSGE$$

Table 1. Gears used in sample fishing

Common name	Vernacular name	Dimensions and attributes	Mesh size (mm)	EGA (sqm)	AOP (sqm) PRM	MON	POM	Year
Triangular push net	Thela Jaal	(1 sqm = 0.5× 1 m × 2 m), operated mainly under water hyacinth covered area	5.0-15.0	1	16620	-	22710	19665
Gill nets	Fansh Jaal	(45 m × 0.75 m), made of monofilament, 10-12 no net each for 70-110 fishers	≥ 22.0	33.75	183380	455050	277290	305240
Long lines	Daun	With 80-100 baits, mainly carnivores caught, operates in coverage area (200 sqm = 200 m × 1 m)	-	200	183380	455050	277290	305240
Seine net	Komor	Fish caught from a type of microsanctuary or FAD created by tree branches	3.0-10.0	333	200000	-	300000	250000
Drag net	Ber Jaal	(50 m × 6 m)	10.0-12.0	300	-	500000	-	500000
Stationary dip net	Bashaal Jaal, Dhenki Jaal	(72 sqm = 0.5 × 12 m × 12 m)	≥ 5.0	72	-	455050	277290	366170
Cone framed cast net	Chaabi Jaal	(7 sqm = 3.14 × 1.5 m × 1.5 m)	≥10.0	7	200000	-	300000	250000
Line and hook	Nal Borshi	Area (1200 sqm = 1000 m × 1.2 m) operates in a line of with 200-250 baits, mainly carnivores caught	-	5.33	183380	455050	277290	305240
Total	8				966760	2320200	1731870	2301555

Abbreviations: EGA, effective gear area; PRM, pre-monsoon; MON, monsoon; POM, post-monsoon; AOP, area of operation; (-), no operation.

where, total sampling gear effort (TSGE) = SEPD (sampling effort/day/gear) x SGD (sampling gear density), g=gram, n=number, e=operation effort.

The overall catch per unit or gear effort (CPUE or CPGE), a measure of relative abundance (n or g/h and n or g/e), was calculated by dividing the total catch in number (n) or wet biomass (g) from gear (s) by total hours (h) or efforts (e) of operations of gear(s) used during those three seasons and the year. Average mean fish density (n/m^3) and standing biomass (g/m^3) was calculated by dividing the total number (n) or wet biomass (g) of fish encountered in an area (m^3) operated by gear (s) for each season.

Statistical analyses determined the mean, standard deviation (SD), and degree of relationships with the help of MS Excel software. The results were then presented in textual, tabular, and graphical form. The level of $P<0.05$ was accepted as statistical significance.

Results

Season-wise and gear-wise CPGE and CPUE are furnished in Table 2. The annual average values of CPGE were calculated as 45.46, 41.19, 403.84, 13750.03, 4583.33, 163.98, 71.77, and 4.36 grams of fish per effort; CPGE (5.45, 4.58, 1.67, 1444.50, 174.17, 30.83, 0.08 and 0.04 fish per effort); CPUE (328.34, 4.12, 36.71, 572.92, 3928.57, 237.78, 235.80, and 0.44 grams of fish per hour of operation), and CPUE (39.33, 0.46, 0.15, 60.19, 149.29, 44.70, 0.27, and 0.004 fish per hour of operation), respectively, for triangular push nets, gill nets, long lines, seine net, drag net, stationary dip net, cone-framed cast net, and line and hook. The lowest CPGE and CPUE values were observed with the line and hook (*Nal Borshi*) during all seasons. The CPUE of triangular push nets during the post-monsoon season was reduced by 14%, to 301.26 g/h from 350 g/h during the pre-monsoon season. Similarly, the pre-monsoon CPUE (g/h) of gill nets was decreased by 1st/4th during monsoon season and by half during the post-monsoon season. The monsoon CPUE (g/h) of the net was also reduced by 37%. In the present study, the pre-monsoon CPUE (g/h) of long lines was decreased by 3rd/4th during monsoon season and by 79% during the post-monsoon season when the monsoon CPUE (g/h) of the gear was also reduced by 1st/5th. The CPUE of the stationary dip nets of the monsoon season was sharply decreased by 2nd/3rd during the post-monsoon season. The pre-monsoon CPUE of the cone-framed cast net was also sharply reduced by 53% during the post-monsoon season. The CPUE of the gear line and hook was drastically reduced by more than 50% during the post-monsoon season of the year in the present study.

Seasonal variations in relative gear dominance and relative catch composition

Maximum fishing duration was observed for seine nets (24 h/d), and the minimum was observed for push nets (4-5 h/d). Drag nets (7 h/d), stationary lift nets (18-22 h/d),

Table 2. Fishing gears employed and their CPUE and CPGE

Season	Gear	Triangular push nets	Gill nets	Long lines	Seine net	Drag net	Stationary dip net	Cone framed cast net	Line and hook	Total
PRM	SGD	1	24	5	2	-	-	33	2500	2565
MON		-	24	10	-	1	1	-	5125	5161
POM		1	24	21	2	-	1	33	2875	2957
YR		2	72	36	4	1	2	66	10500	10683
PRM	SEPD	28	1	1	1	-	-	33	1	65
MON		-	1	1	-	6	35	-	1	44
POM		37	1	1	1	-	23	13	1	77
YR		33	1	1	1	6	29	23	1	95
PRM	SEHPD	5	10	11	24	-	-	7	10	67
MON		-	10	11	-	7	22	-	10	60
POM		4	10	11	24	-	18	7	10	84
Year		4.5	10	11	24	7	20	7	10	94
PRM	TSGE	28	24	5	2	-	-	1089	2500	3648
MON		-	24	10	-	6	35	-	5125	5200
POM		37	24	21	2	-	23	429	2875	3411
YR		65	72	36	4	6	58	1518	10500	12259
PRM	TSEH	5	240	55	48	-	-	231	25000	25579
MON		-	240	110	-	7	22	-	51250	51629
POM		4	240	231	48	-	18	231	28750	29522
YR		9	720	396	96	7	40	462	105000	106730
PRM	TSGCB	1750	1324	6100	27500	-	-	74250	13090	124014
MON		-	1005	3100	-	27500	7500	-	25625	64730
POM		1205	637	5338	27500	-	2011	34690	7033	78414
Year		2955	2965	14538	55000	27500	9511	108940	45748	267158
PRM	TSGCN	124	141	20	1876	-	-	79	108	2348
MON		-	126	21	-	1045	1304	-	230	2726
POM		230	63	19	3902	-	484	45	56	4799
Year		354	330	60	5778	1045	1788	124	394	9873
PRM	CPGE (g/e)	62.50	55.16	1220.00	13750.04	-	-	68.18	5.24	15161
MON		-	41.86	310.00	-	4583.33	214.29	-	5.00	5154
POM		32.57	26.54	254.20	13750.02	-	87.43	80.86	2.45	14234
Season Average		47.53	41.19	594.74	13750.03	4583.33	150.86	74.52	4.23	19246
Year average		45.46	41.19	403.84	13750.03	4583.33	163.98	71.77	4.36	19064
PRM	CPGE (n/e)	4.43	5.88	4.00	938.00	-	-	0.07	0.04	952
MON		-	5.25	2.10	-	174.17	37.26	-	0.04	219
POM		6.22	2.63	0.90	1951.00	-	21.04	0.10	0.02	1982
Season Average		5.32	4.58	2.33	1444.50	174.17	29.15	0.09	0.04	1660
Year average		5.45	4.58	1.67	1444.50	174.17	30.83	0.08	0.04	1661
PRM	CPUE (g/h)	350.00	5.52	110.91	572.92	-	-	321.43	0.52	1361
MON		-	4.19	28.18	-	3928.57	340.91	-	0.50	4302
POM		301.26	2.65	23.11	572.92	-	111.72	150.17	0.24	1162
Season Average		325.63	4.12	54.07	572.92	3928.57	226.32	235.80	0.42	5348
Year average		328.34	4.12	36.71	572.92	3928.57	237.78	235.80	0.44	5345
PRM	CPUE (n/h)	24.80	0.59	0.36	39.08	-	-	0.34	0.004	65
MON		-	0.53	0.19	-	149.29	59.27	-	0.004	209
POM		57.50	0.26	0.08	81.29	-	26.89	0.19	0.002	166
Season Average		41.15	0.46	0.21	60.19	149.29	43.08	0.27	0.004	295
Year average		39.33	0.46	0.15	60.19	149.29	44.70	0.27	0.004	294

Abbreviations: SGD, sampling gear density; SEPD, sampling effort per day per gear; TSGE, total sampling gear effort; SEHPD, sampling efforts hrs per day per gear; TSEH, total sampling effort hours; TSGCB, total sampling gear catch in biomass; TSGCN, total sampling gear catch in number; CPGE, catch per gear effort (g/e or n/e), TSGC/TSGE, or TSGCN/TSGE; CPUE, catch per unit effort (g/h or n/h)=TSGCB/TSEH or TSGCN/TSEH; g, gram; n, number; e, effort; h, hour; PRM, pre-monsoon; MON, monsoon; POM, post-monsoon, (-), no operation.

and line and hook (10 h/d) had the highest and lowest gear operator densities during the post-monsoon and monsoon seasons, respectively. The seine net followed by the gill net were seen to be used the most and the drag net was used the least by gear operators in the present study. The stationary lift net and long lines (Daun Borshi) made fourth and fifth position, respectively, in the oxbow lake of the present study. Seasonal variations in relative gear dominance (RGD) revealed the gear line and hook made its dominant presence (>71%) in the lake throughout the year in terms of numbers (Table 3). The stationary dip net showed maximum relative catch composition both in biomass (RCB) and numbers (RCN) throughout the year except during the pre-monsoon season when the cone-framed cast net hauled in the maximum catch in biomass (31.51%) and the gill nets contributed the maximum number of fish (64.92%). The seine net operation appeared to be the least dense among all gears throughout the year except during the monsoon season when the drag net had the least operation. Annual variations in relative fish abundance both in terms of catch biomass and numbers in relation to dominance and CPUE of different fishing gears are furnished in Figure 2.

Discussion

Gear density was inversely related with gear catch throughout the year for the biomass and for the numbers with the exception of the pre-monsoon season. Seasonal variations in correlation coefficients of gear densities and gear catches during all three seasons of the year are given in Table 4. Gear densities among all seasons were strongly correlated, whereas gear catches in biomass of the three seasons were weakly correlated. Gear catches in numbers were also strongly correlated in those three seasons, like its density, with the exception of the post-monsoon season. All the gears in the present study exhibited lower CPUE during the monsoon and post-monsoon seasons compared to the pre-monsoon season. This might be due to over-exploitation by the fishers and swelled water spread area due to influx from the Ganga River. Fishers in the present study generally were observed to use multiple gears enhancing the density of the gear operators. That was extended to increase their earnings through catching without increasing the number of fishers in the oxbow lake. The present findings regarding different fishing gears are in full or partial agreement with the results of other similar studies (4-6,8,9,11,14).

The mean CPUE of gears employed in the Chhariganga oxbow lake under study varied due to the gear dimensions, density and pressure, luring ingredients, the catchers' preferences of fishing places and, of course, their experience and expertise. The CPUE showed fluctuating trends during the study period due to the influx of fish along with flood waters entering the oxbow lake during the monsoon season and subsequently the heavy fishing pressure and jute retting (1-3) during the monsoon and post-monsoon seasons. However, the fish availability and catch decreased in the post-monsoon season and increased again in the pre-monsoon season. Except the line and hook, gill net, cone-framed cast net, and long lines, other gears had a moderately higher annual CPUE for both fish biomass and numbers in the present study, indicating the comparatively more harmful impacts of those gears on fish abundance. This result concurs partially with the findings of other studies (1,15).

The CPUEs of all the fishing gears of the studied oxbow lake ecosystem were much lower than the values obtained in the study on floodplain *Beels* in Bangladesh (15). This result may be attributable to the variations in their geographical and anthropological parameters. The findings of the current study regarding the CPUE of different fishing gears are also in full or partial agreement with the results of other similar studies (6,9-13).

The oxbow lake in the present study is a moderately to poorly productive body of water the fish abundance of which is decreasing (2,3). Fishing nets were found to be the most harmful among all studied gears (1). The indiscriminate use of fishing gear with varied mesh sizes

Table 3. Seasonal variations in relative gear dominance and relative catch composition (%)

Gear catch	PRM			MON			POM			Year total		
	RGD	RCB	RCN	RGD	RCB	RCN	RGD	RCB	RCN	RGD	RCB	RCN
Triangular push nets	0.60	20.79	30.61	-	-	-	0.73	26.74	33.84	0.53	12.66	15.13
Gill nets	26.72	29.33	64.92	18.23	19.12	18.89	21.74	17.45	11.45	21.25	21.99	23.07
Long lines	0.40	9.66	0.66	0.86	6.71	0.36	0.55	4.23	0.10	0.65	7.09	0.32
Seine net	0.28	1.30	1.84	-	-	-	0.26	1.82	1.71	0.22	0.82	0.81
Drag net	-	-	-	0.02	7.22	2.16	-	-	-	0.02	3.29	1.17
Stationary dip net	-	-	-	0.33	56.85	77.87	0.55	32.91	52.51	0.46	33.38	58.72
Cone framed cast net	0.94	31.51	0.70	-	-	-	0.85	11.28	0.10	0.71	12.56	0.13
Line and hook	71.06	7.41	1.27	80.56	10.09	0.71	75.30	5.57	0.29	76.15	8.22	0.66
Total	100	100	100	100	100	100	100	100	100	100	100	100

Abbreviations: RGD, relative gear dominance; RCB, relative catch biomass; RCN, relative catch numbers; PRM, pre-monsoon; MON, monsoon; POM, post-monsoon.

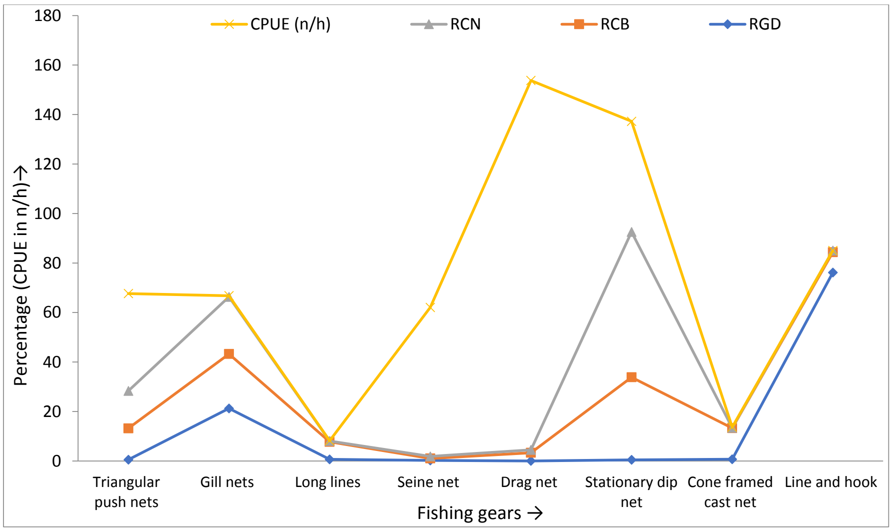

Figure 2. Annual variations in fish abundance with dominance and CPUE of different fishing gears.
Abbreviations: RGD, relative gear dominance; RCB, relative catch biomass; RCN, relative catch numbers; CPUE, catch per unit effort (n/h); n, number; h, hour.

Table 4. Seasonal variations in correlation coefficients of gear density and catch

	Gear Density			Gear Catch (Biomass)			Gear Catch (numbers)		
	MON	POM	YR	MON	POM	YR	MON	POM	YR
PRM	0.986	0.996	0.995	0.94	0.66	0.86	1.00	0.56	0.99
MON		0.998	0.998		0.97	0.93		1.00	0.99
POM			1.000			0.85			0.90

should be regulated and prevented so as to arrest the decreasing trend in fish abundance in the present oxbow lake. The findings from the present study will reveal the way for the planning and management of sustainable fisheries and the conservation of these natural resources at a national level.

Conclusion
Indiscriminate use of fishing gears, particularly the line and hook, gill net, cone-framed cast net, and long lines, demand regulations and preventions to provide for a higher fish abundance in the present oxbow lake in years to come.

Authors' contributions
All authors contributed equally and participated in the collection, analysis, and interpretation of the data. All authors critically reviewed, refined, and approved the

Competing interests
The authors declare that they have no competing interests.

Ethical issues
It is confirmed that this manuscript is the original work of the authors. It has not been published, nor is it under review in another journal, and it is not being submitted for publication elsewhere.

Acknowledgements
Authors acknowledge the research facilities and/or other help and cooperation extended by Department of Ecological Studies, University of Kalyani, Department of Fisheries, Government of West Bengal and Kutirpara Fishermen Cooperative Society associated with Chhariganga Oxbow lake.

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