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Research article

Catch composition, catch per unit effort (CPUE) and species selectivity of fishing gears on multi-species Kaptai Lake in Bangladesh

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A R T I C L E I N F O

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A B S T R A C T

Kaptai Lake, the largest artificial reservoir in Southeast Asia, is home to a diverse fish fauna that supports thousands of livelihoods and is distinguished by multi-species and multi-gear fisheries. In Kaptai Lake, the gear-based catch composition, catch rate and distribution pattern are little known. From August 2020 to April 2021, a nine-month study was conducted in five *upazilas* using direct catch assessment surveys and fishing effort surveys from four fishing gears, namely seine nets, gill nets, lift nets, and push nets. A total of 49 morpho-species from 22 families were found, with three species from the Clupeidae accounting for 93.63 % of the catch in all gear combined. The total catch composition and CPUE were higher in seine nets (75.07 %, 13.86 ± 1.8 kg/gear/trip respectively) and lower in lift nets (4.97 %, 1.01 ± 0.21 kg/gear/trip) and showed significant differences among gears, except sampling sites whereas CPUE was higher in Naniarchar for seine nets (17.29 ± 8.89 kg/gear/trip) and lower in Langadu for lift nets (0.62 ± 0.25 kg/gear/trip). Seine nets captured more species, and the number of species increased significantly as CPUE increased. Our study assessed four gears that targeted different fish species with little overlap in leading species; seine nets and gill nets primarily targeted Clupeidae (96.53 % and 41.69 %, respectively), whereas lift nets and push nets primarily targeted Cyprinidae and Palaemonidae (38.93 % and 99.37 % respectively). The observed abundance and variety of fish species captured in gill nets suggest a significant overlap in the selectivity of this fishing method with that of lift nets. Due to the varying contributions of sites and gears, the nMDS ordination pattern reveals a weak spatial variation in catch composition. According to the SIMPER results, Bagridae, Gobiidae, and Ambassidae were the most significant contributors to site grouping patterns across all gears. Furthermore, the findings indicate that the catch composition does not follow the typical pattern of spatial variation. By implementing measures to eliminate or decrease the usage of small mesh nets, there is expected to be a corresponding decrease in the capture of small fish. Additionally, this action will help mitigate the issue of overlapping selectivity among the current fishing gears. Our findings provide baseline data on the potential efficacy of gear limitation and suggest a gear-based management strategy.

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1. Introduction

In the northeastern region of Bangladesh, the H-shaped Kaptai Lake is one of the largest artificial freshwater reservoirs in South-East Asia and is home to a variety of fish and fishery resources, particularly for small indigenous species [1–4]. This inland watershed was formed in 1961 due to the construction of an artificial earth dam on the Karnaphuli River as part of the Karnaphuli hydroelectric project. The reservoir has an area of approximately 68,800 ha, with a water surface area of 58,300 ha [5]. Its average and maximum water depths are approximately 9 m and 32 m, respectively [6] and constitute a significant component of the inland watershed, accounting for 46.8 percent of the country's total pond area [7].

The current fish production of Kaptai Lake is 17,937 metric tons (MT) which covers 0.38 % of the total fish production in Bangladesh (4.76 million metric tons) [8]. The lake primarily supports artisanal to medium-scale commercial fishing [9] and is managed and controlled by the Bangladesh Fisheries Development Corporation [10]. In January 1963, fishing on Kaptai Lake was first conducted using only three types of gear such as seine nets, gill nets, and hooks and lines [11]. Due to the multispecies nature of the fishery, a variety of traditional fishing nets such as lift nets, mosquito seine nets, gill nets, current nets, push nets, and a range of fishing traps are used to collect and commercially exploit the fish [9]. According to BFRI-RSS [12], approximately 679 gill nets, 305 seine nets, 93 lift nets, 18 push nets, and 212 hooks and lines of various sorts are used.

The target fish species and the density of the fish stock in that reservoir determine the type of gear used in a water body. It has been discovered that all fishing gear used in Kaptai Lake is selective to some extent, either by species, size, or a combination of these attributes, making them practical management options. There are few studies on the effect of fishing gears on species diversity, species selectivity and catch composition in Kaptai lake [9]. Seine nets may capture a wide range of species, with only the tiniest individuals evading capture [13,14]. Small meshed seine net (mosquito nets) has been widely utilized since the 1980s due to the dramatic proliferation of clupeids, and their use has increased in recent years [3]. Gill nets can also catch a large range of species, although they can be quite size-selective, catching only a very small range of lengths depending on the mesh size [15]. As a result, the kind and application of fishing gear can influence the efficiency of fish capture and the selectivity and composition of fish resources. According to Ahmed and Hambrey [9], small-meshed seine nets were used to capture Clupeidae, Bagridae, Cyprinidae, and Schilbeidae, whereas gill nets targeted Cyprinidae, Bagridae, Notopteridae, and Cichlidae. Bagridae, Cyprinidae, Schilbeidae, Notopteridae, and Cichlidae are also easily captured using the lift net with four distinct mesh sizes. The excessive usage of gear complicates the estimation and standardization of fishing efforts in the open water of Lake Kaptai, therefore the effects of the different gears employed on the lake must be assessed individually rather than collectively [9].

Kaptai Lake is one of the most diversified watersheds, home to over 74 fish species, six of which are exotic [16]. A total of 76 fish

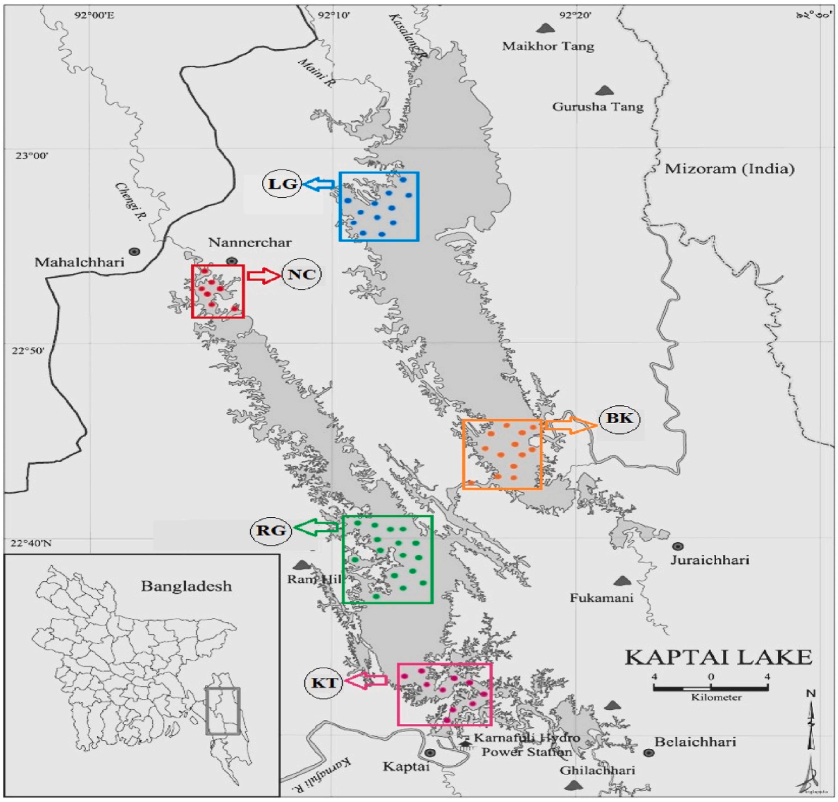

Fig. 1. Map showing the sampling location in Kaptai lake. LG: Langadu; NC: Nannierchar; BK: Barkal; RG: Rangamati sadar; KT: Kaptai.

species from 10 orders, including 2 crab species and 7 prawn species, were found in the lake [10]. A total of 36 valuable species were harvested for commercial purposes [17], but the lake's output was initially dominated by clupeids, specifically three prominent species: *Gudusia chapra*, *Gonialosa manmina*, and *Corica soborna*, which together accounted for 64 % of the total fish production in 2018–2019 [18]. Consequently, the production of important carp species and high-value fish in Kaptai Lake has steadily declining over time, despite the lake's notoriety as a breeding ground for important carp species [17,19].

Fishing effort is commonly expressed as a catch per unit effort (CPUE), which is easier to measure/monitor than direct estimations of target species abundance [20–22]. It is a valuable matrix for determining the sustainable use of fishing gear in relation to the amount and exploitation of fisheries resources, and assessing fishing vulnerability based on predicted total production [23]. CPUE is a measurement of fish stocking density, physical and financial productivity indices, and fishing activity efficiency [24].

Although Kaptai Lake provides many environmental benefits and is home to a variety of fish fauna, suffering from multidimensional natural and ethnographic pressures that threaten ecological sustainability and the gradual reduction of biodiversity. Therefore, it is more important to work rationally on accessible fishing gears in the Kaptai reservoir including gear efficiency, gear-based catch composition and catch per unit effort (CPUE), gear selectivity and fish diversity index. Considering all stress issues, this study aimed to assess the catch composition, fish assemblages, CPUE and species selectivity of fishing gears used in the Kaptai lake fishery.

2. Materials and methods

2.1. Study area

This H-shaped lake has two arms connected by a narrow canyon close to Shubalong in the Barkal *upazila*, which was once the path of the Karnaphuli River. Chengi stream in the north nourished the lake region of Naniarchar *upazila*, and Reinkhiyong stream in the south fed the lake region of Kaptai *upazila*, which are both located in the lake's left arm. The right arm of Langadu *upazila* receives water from the Miyani and Kassalong streams and the Karnaphuli river on the side [25]. Taking into account the water inflow area and major fishing grounds in the Kaptai Reservoir, this research was conducted in five distinct *upazillas* of the Rangamati district: Rangamati Sadar (RG), Barkal (BK), Naniarchar (NC), Langadu (LG), and Kaptai (KT) (Fig. 1) [25,26].

2.2. Gear and data collection

Three sites were sampled each month for a total of 27 fishing trips over the course of the study due to financial restraints. Fish samples were taken from 160 different fishing gears over the course of 27 fishing trips (87 seine nets, 50 gill nets, 13 lift nets and 10 push nets). Seine net, also referred to as a small meshed mosquito net (mesh size 0.2–1.8 cm), is the most popular manual gear in Kaptai Lake due to its large size (length 375–2700 feet; width 42–75 feet), which allows it to collect fish at any depth. Six to ten people operate this net from a boat or the shore depending on the surrounding water areas. Gill nets are manually operated by one or two fishermen in pelagic water from a fishing vessel. They can be either small-mesh (*Chapila jal*/current net; mesh size: 0.5–5.0 cm; length: 190–900 feet) or large-mesh (*Vasa jal/sutar jal*/ayre net; mesh size: 5.0–10.0 cm; length: 500–900 feet). Square-shaped lift nets (*Dharma jal*) of varying mesh sizes (from as few as four to six) are manually towed behind four boats by a crew of eight to ten fishermen. Polyethylene netting is used to make it, with a mesh size of 0.5–0.7 cm in the center and gradually increasing to 3.5–8.0 cm, 12–16.5 cm, 15–22 cm, and 20–28 cm at the periphery. Push net/mosquito peeling net (*Thela jal*; mesh size: 0.2 cm) is a triangular bag-shaped net typically cast from a small boat or by wading in the littoral zone. It is secured to a bamboo frame resembling crossed scissors with rope. The majority of fishing grounds in Kaptai Lake were fished with these fishing gear.

Fishing is prohibited in this reservoir during the fish breeding season (May–July or August), as mandated by the Fish Act of 1950 [27]. As a result, a nine-month study (August 2020 to April 2021) was conducted to collect samples using a direct catch assessment survey (CAS) and a fishing effort survey (FES). Fish samples were collected on a monthly basis (from randomly selected fishing vessels) through direct observation of the fish species caught by fishermen using various fishing gears such as seine nets, gill nets, lift nets, and push nets. In the majority of instances, the entire sample was taken from small catches and 10 % of subsamples were taken from large catches while fishing. Crushed ice was used to preserve samples in the icebox before they were taken to the lab. The collected fish sample was sorted and identified up to species level by examining their morphometric and meristic features using IUCN Bangladesh [28]; Rahman [29] and FAO fish identification sheets [30]. The number of individuals, as well as the number of fishermen in each vessel, the fishing duration, and the fishing efforts for each gear were recorded.

2.3. Data processing and statistical analysis

The relative abundance was calculated as a percentage of the number of species caught by each gear and all gears combined. The total abundance of species for each site was calculated as a percentage of the total number of fish caught using each gear and all gears combined. To examine for differences in catch composition and species diversity among sites and gear types, PERMANOVA and 2-way ANOVA were performed, respectively.

The Catch per Unit Effort (CPUE) was computed as kg/gear/trip by dividing the total biomass (kg) per trip by the number of gears used. Species richness was presented as the number of species recorded per trip per gear. The CPUE and species richness were log-transformed for linear regression analysis to estimate the species richness at different catch rates. A 2-way ANOVA was used to compare species richness and CPUE differences between gear types and sampling sites. The post-hoc test was used to compare the CPUE of different gears.

Non-metric Multidimensional Scaling (nMDS), 2-way ANOSIM, and 2-way SIMPER were used to investigate spatial changes in species composition among gears and sampling sites. To test for differences in catch composition among gears across sampling sites, a 2-way ANOSIM was used. A two-way SIMPER analysis was also performed to determine which fish species contributed to differences in gear and fishing areas. Tukey's post hoc tests were used to examine significant differences ($P < 0.05$) between gears from different sample locations. All inferential statistics were employed using PAST software (version 4.07) and significant at less than 5 % P-values.

3. Results

3.1. Faunal composition and diversity

During the study period, a total of 3,09,148 fish individuals were counted, representing 22 families and 49 distinct morpho species. Precisely, 41 species across 2,97,444 individuals were captured by seine net, 33 species across 5519 individuals by gill net, 14 species across 1305 individuals by lift net and 9 species across 5083 individuals by push net (Fig. 2a and b). Fish catch composition differed significantly between sampling sites (PERMANOVA, $F = 2.3202$, $P < 0.05$) and gears employed (PERMANOVA, $F = 5.7637$, $P < 0.05$). Furthermore, there was no significant interaction between sampling site and gear type (PERMANOVA, $F = 0.62551$, $P > 0.05$; Table 1). However, the seine net contributed the most catches (75.07 %), followed by the gill net (10.15 %), the push net (9.81 %), and the lift net (4.97 %) (Fig. 2c). The seine net dominated relative catch composition in all sampling sites except Barkal (BK). There was no lift net found at Kaptai and Naniarchar. Catches from push net were found only at Barkal, which made a substantial contribution (9.81 %) to the total catch (Fig. 2d). The results of two-way ANOVA revealed that there were significant changes in species diversity depending on the type of fishing gear used ($F = 5.954$, $P < 0.05$), but not between sites ($F = 2.155$, $P > 0.05$), or when gear and sample site were combined ($F = 0.2553$, $P > 0.05$).

3.2. Species selectivity of gears

Clupeidae was the most species-rich family (93.63 %), followed by Palaemonidae (2.47 %), and Gobiidae (0.97 %), with a total of 19 families accounting for the remaining 2.93 % when all gears were combined (Table 2). Clupeidae dominated seine net and gill net catches (96.53 % for seine net and 41.69 % for gill net, respectively), whereas Cyprinidae and Palaemonidae were the most species-rich families for lift net (38.93 %) and push net (99.37 %), respectively (Table 2). Catches from both the seine net and the push net were significantly dominated by a single species, presumably indicating the species selectivity of the gears; *Corica soborna* dominated the seine net (85.25 %, Fig. 3a), while *Macrobrachium lamarrei* was the most important species for the push net (99.35 %, Fig. 3d). Unlike

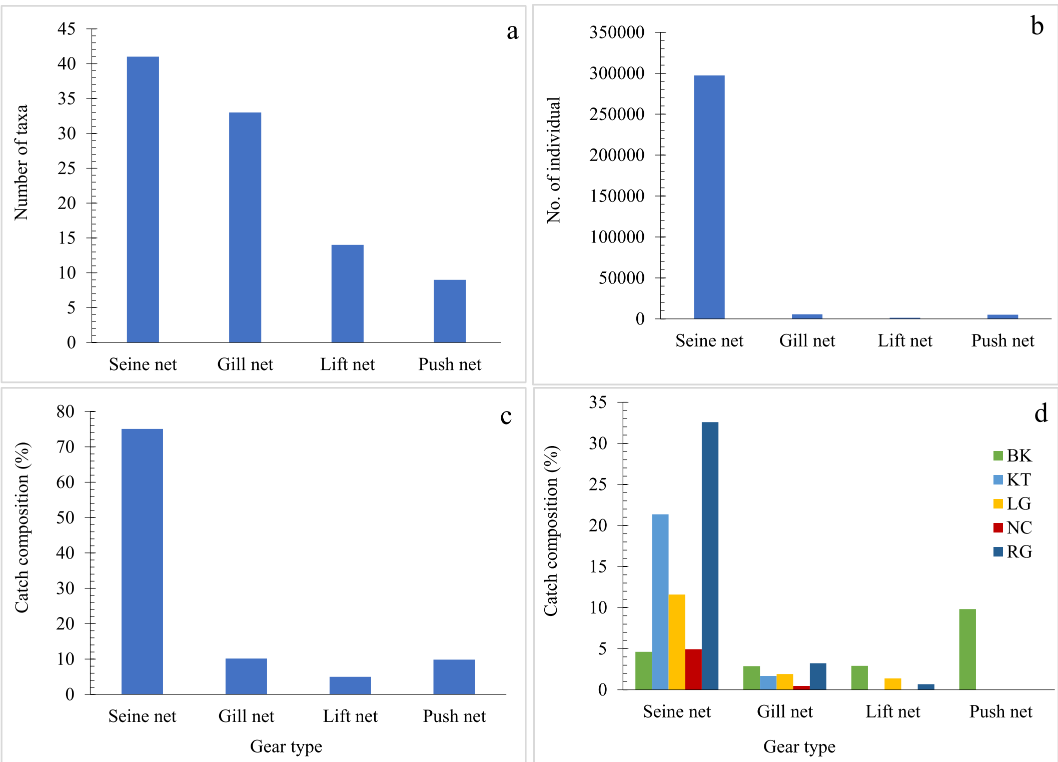

Fig. 2. Comparison of the taxon (a), individual (b), proportion of total catch by number across gear types (c) and gear types per sampling site (d).

Table 1
PERMANOVA analysis on fish catch composition of fishing net used in Kaptai lake.

Source	Sum of sqrt	df	Mean square	F	*P*
Site	3.3148	4	0.8287	2.3202	0.0002[a]
Gear	6.17569	3	2.0586	5.7637	0.0001[a]
Interaction	2.68088	12	0.22341	0.62551	0.057
Residual	48.2169	135	0.35716		
Total	60.388	154			

Significant differences are indicated with the asterisk (*).
[a] $P < 0.01$.

the seine and push nets, the gill net and lift net captures were dominated by four species, accounting for 79.74 % and 91.19 % of the total catches, respectively. The most dominant species of gill net were *G. chapra* (37.96 %), *A. colia* (22.92 %), *O. cotio* (10.55 %) and *G. giuris* (8.32 %, Fig. 3b); while *O. cotio* (38.85 %), *G. giuris* (27.51 %), *C. nama* (12.78 %) and *G. chapra* (12.03 %) were the most important species for lift net (Fig. 3c).

3.3. Catch per unit effort (CPUE)

Mean CPUE was significantly different among gears (2-way ANOVA: F = 18.58, $P < 0.05$). Mean CPUE for seine net was 13.86 ± 1.8 kg/gear/trip compared to gill net (1.96 ± 0.22), lift net (1.01 ± 0.21) and push net (3.55 ± 0.82) (Fig. 4a). A post hoc test revealed significant differences in CPUE between seine net and gill net ($P = 0.003$), seine net and lift net ($P = 0.006$), and seine net and push net ($P = 0.003$). Furthermore, there were no significant variations in catch rate between sites (2-way ANOVA: F = 2.155, $P > 0.05$) (Fig. 4b), whereas catch rate for seine net was greater in Naniarchar (17.29 ± 8.89) and lower in Kaptai (7.8 ± 1.86). Mean CPUE for gill net was higher in Langadu (2.999 ± 0.71) and lower in Naniarchar (1.49 ± 0.69). On the other hand, the interaction between the sampling site and gear showed no significant differences (2-way ANOVA: F = 0.2553, $P > 0.05$).

Fig. 5 depicts the relationships between fish species diversity and CPUE for various fishing gears as measured by linear regressions. The linear model for species richness and CPUE was shown to be significantly positive ($P < 0.05$) for seine net, but not for gill net ($P = 0.81$), lift net ($P = 0.86$) or push net ($P = 0.47$). However, the fit was greater for seine net ($r^2 = 0.14$) followed by push net ($r^2 = 0.05$), gill net ($r^2 = 0.02$) and lift net ($r^2 = 0.01$).

3.4. Spatial variations in species composition

The 2D nMDS analysis showed the groupings of fish composition data by gear types across different sampling sites, based on post-hoc test (Fig. 6). The nMDS ordination pattern of fish catch composition data showed a stress value of 0.25 for both gear used (Fig. 6a) and sample sites (Fig. 6b), indicating a poor pattern. The 2-way ANOSIM result revealed significant differences in fish species

Table 2
Number of individual and relative abundance of fish families for selected gears in all sampling sites.

Fish family	Seine net		Gill net		Lift net		Push net		Combined gear	
	Inds.	%	Inds.	%	Inds.	%	Inds.	%	Inds.	%
Clupeidae	287001	96.53	2264	41.69	180	13.79	–	–	289445	93.63
Palaemonidae	2532	0.85	52	0.96	5	0.38	5051	99.37	7640	2.47
Gobiidae	2183	0.73	459	8.45	359	27.51	–	–	3001	0.97
Cyprinidae	1188	0.4	654	12.04	508	38.93	–	–	2350	0.76
Schilbeidae	938	0.32	1289	23.73	28	2.15	–	–	2255	0.73
Ambassidae	1595	0.54	235	4.33	180	13.79	1	0.02	2011	0.65
Hemiramphidae	1671	0.56	–	–	–	–	–	–	1671	0.54
Mastacembelidae	76	0.03	141	2.60	–	–	4	0.08	221	0.07
Bagridae	64	0.02	108	1.99	38	2.91	–	–	210	0.07
Sciaenidae	4	0.001	165	3.04	–	–	–	–	169	0.05
Belonidae	60	0.02	4	0.07	–	–	–	–	64	0.02
Cichlidae	1	0.0003	46	0.85	7	0.54	–	–	54	0.02
Badidae	1	0.0003	–	–	–	–	18	0.35	19	0.006
Cobitidae	7	0.002	2	0.04	–	–	–	–	9	0.003
Heteropneustidae	–	–	7	0.13	–	–	1	0.02	8	0.003
Osphronemidae	1	0.0003	–	–	–	–	4	0.08	5	0.002
Siluridae	4	0.001	–	–	–	–	–	–	4	0.001
Sisoridae	1	0.0003	2	0.04	–	–	–	–	3	0.001
Aplocheilidae	1	0.0003	–	–	–	–	2	0.04	3	0.001
Channidae	–	–	1	0.02	–	–	2	0.04	3	0.001
Notopteridae	1	0.0003	1	0.02	–	–	–	–	2	0.0006
Mugilidae	–	–	1	0.02	–	–	–	–	1	0.0003

Inds. = Individual.

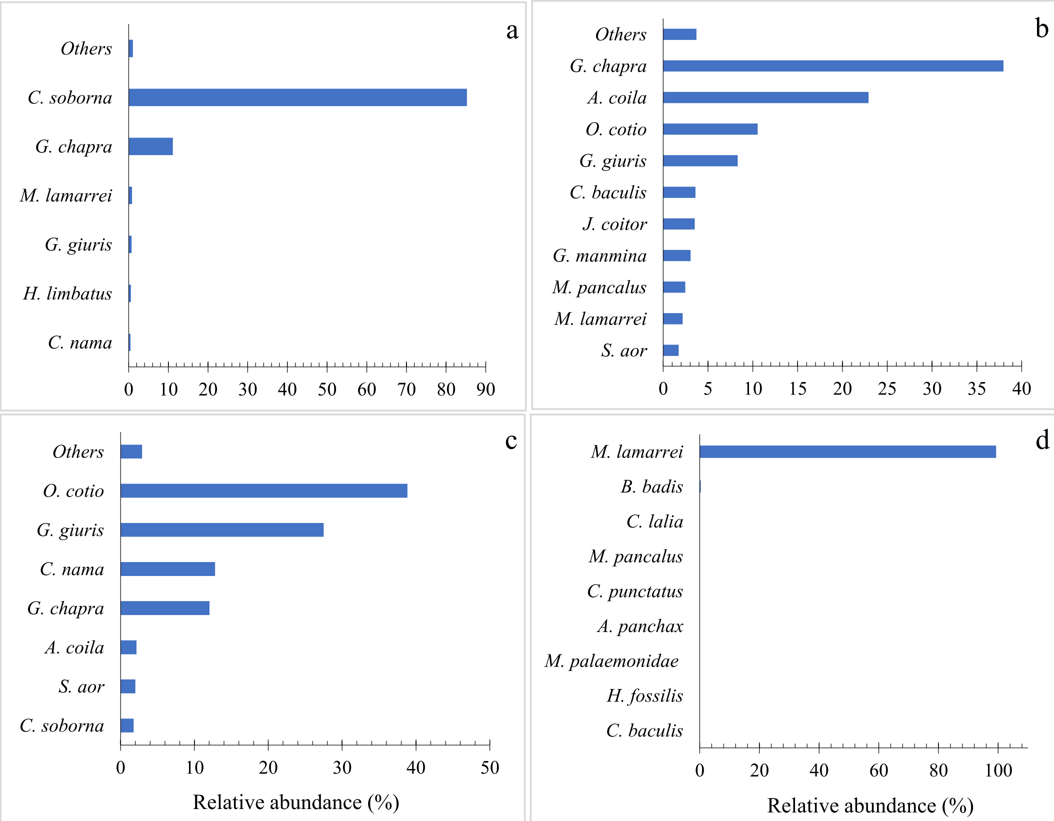

Fig. 3. Relative abundance (%) of the leading fish species for selected gears from all sampling sites.

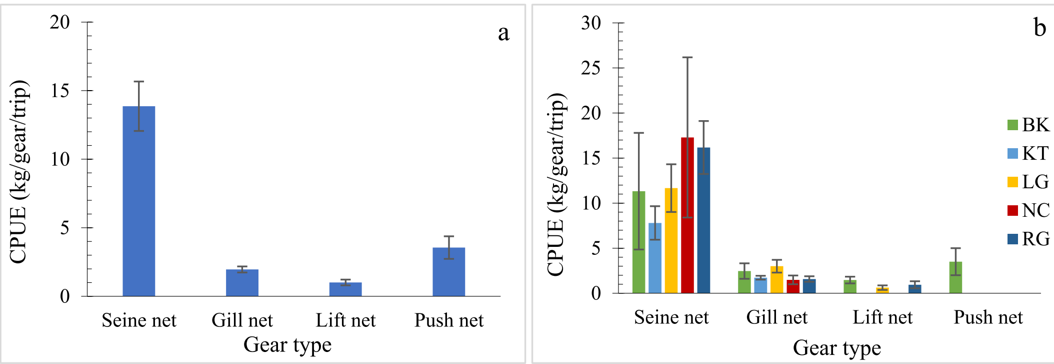

Fig. 4. Comparison of catch per unit effort (CPUE) across gear types (a) and gear types per sampling site (b).

composition between gear types and study sites (R = 0.35; $P = 0.0001$) and study sites (R = 0.23; $P = 0.0001$). Post-hoc comparisons revealed significant variations in species composition between seine net and gill net ($P < 0.01$) as well as between seine net and lift net ($P < 0.05$).

The SIMPER analysis revealed that the overall average dissimilarity between sites and gears was 16.67 % and 14.45 %, respectively and the difference was primarily driven by Bagridae in study sites (contributed 9.995 %) and Gobiidae in gear used (contributed 9.906 %) (Table 3). Furthermore, the SIMPER analysis within different gears used during the study period revealed the highest average dissimilarity within lift net (42.77 %), followed by push net (40.0 %), gill net (16.13 %), and seine net (13.53 %), with the difference primarily driven by Cichlidae in lift net (16.55 %), Palaemonidae in push net (20.61 %), Gobiidae in gill net (12.5 %) and seine net (12.42 %) (Table 4). The average dissimilarity based on study sites was 49.44 % in Naniarchar, 30.33 % in Barkal, 25.62 % in Kaptai, 22.71 % in Langadu, and 16.64 % in Rangamati Sadar. Furthermore, Bagridae had the greatest dissimilarity in all study sites except Naniarchar (Cyprinidae; contributed 17.91 %) (Table 5).

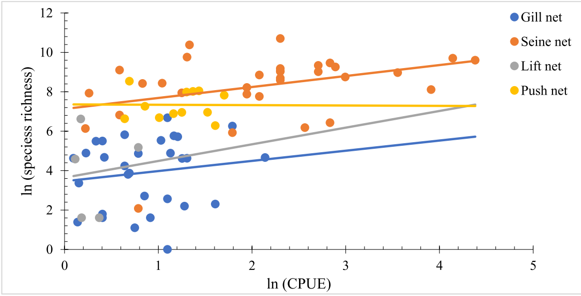

Fig. 5. Relationship between species richness and catch per unit effort (CPUE). Data were log-transformed for normality. *P*-value for linear model is presented at 95 % confidence interval.

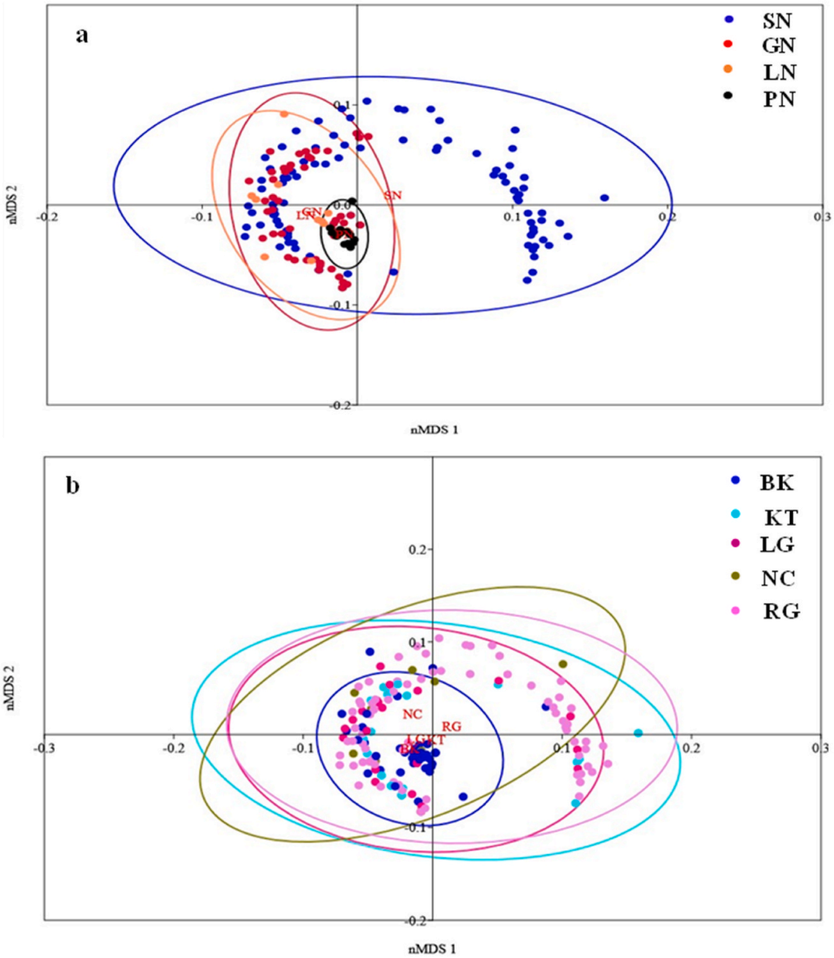

Fig. 6. 2D Non-metric multidimensional scaling (nMDS) plots of catch composition data (Bray-Curtis similarity) [square root transformed data] based on gear (a) and studies sites (b) during the entire sampling period (2D stress: 0.25). SN: Seine net; GN: Gill net; LN: Lift net; PN: Push net; BK: Barkal; KT: Kaptai; LG: Langadu; NC: Naniarchar; RG: Rangamati Sadar.

4. Discussion

4.1. Faunal composition and diversity

This study demonstrated the differences in fish species captured by selective fishing nets such as the seine net, gill net, push net, and lift net in the multi-species kaptai reservoir. Significant changes in species composition across the gears point to the partitioning of fish

Table 3
SIMPER analysis showing catch composition for selected gears combined in study areas.

Based on site			Based on gear		
Taxon	Average dissimilarity	Contrib. %	Taxon	Average dissimilarity	Contrib. %
Bagridae	1.636	9.995	Gobiidae	1.431	9.906
Ambassidae	1.473	8.996	Ambassidae	1.426	9.868
Gobiidae	1.454	8.879	Bagridae	1.36	9.409
Schilbeidae	1.273	7.776	Schilbeidae	1.208	8.363
Cyprinidae	1.21	7.391	Cyprinidae	1.197	8.286
Hemiramphidae	1.202	7.343	Hemiramphidae	1.11	7.68
Palaemonidae	1.123	6.859	Palaemonidae	1.046	7.239
Mastacembelidae	0.962	5.876	Mastacembelidae	0.8936	6.184
Clupeidae	0.8234	5.029	Clupeidae	0.6942	4.804

Table 4
SIMPER analysis for catch composition based on gears.

Taxon	Average Dissimilarity				Contribution (%)			
	Seine net	Gill net	Lift net	Push net	Seine net	Gill net	Lift net	Push net
Gobiidae	1.68	2.017	5.761	–	12.42	12.5	13.47	–
Hemiramphidae	1.659	–	–	–	12.27	–	–	–
Ambassidae	1.606	1.89	5.109	0.6061	11.88	11.72	11.94	1.515
Cyprinidae	1.49	1.127	5.959	–	11.01	6.989	13.93	–
Palaemonidae	1.436	0.4104	5.779	20.61	10.61	2.544	13.51	51.52
Schilbeidae	1.367	1.84	3.906	–	10.11	11.41	9.133	–
Bagridae	0.9542	1.996	2.896	–	7.055	12.37	6.77	–
Mastacembelidae	0.8722	1.543	–	2.424	6.448	9.565	–	6.061
Belonidae	0.5369	0.423	–	–	3.969	2.622	–	–
Cobitidae	0.3749	0.2269	–	–	2.772	1.407	–	–
Sciaenidae	0.2824	1.241	–	–	2.088	7.696	–	–
Siluridae	0.2436	–	–	–	1.801	–	–	–
Clupeidae	0.2018	1.363	6.282	–	1.492	8.449	14.69	–
Cichlidae	0.17	0.5977	7.081	–	1.257	3.706	16.55	–
Notopteridae	0.17	0.1944	–	–	1.257	1.205	–	–
Osphronemidae	0.17	–	–	2.424	1.257	–	–	6.061
Aplocheilidae	0.1438	–	–	1.212	1.063	–	–	3.03
Sisoridae	0.08373	0.2406	–	–	0.6191	1.492	–	–
Badidae	0.08373		–	10.91	0.6191		–	27.27
Heteropneustidae	–	0.5571	–	0.6061	–	3.454	–	1.515
Mugilidae	–	0.2406	–	–	–	1.492	–	–
Channidae	–	0.2224	–	1.212	–	1.379	–	3.03

species. Both the seine net and the gill net targeted a wide variety of fish, but the huge catch was caught by the seine net, and both were dominated by Clupeidae. Ahmed and Hambrey [9] demonstrated that Clupeidae and Cyprinidae were the leading species caught with seine nets and gill nets, respectively. In the present investigation, the catch composition of lift nets was dominated by Cyprinidae, whereas Ahmed and Hambrey [9] discovered that Bagridae predominated. This difference could be explained by the choice of survey period, the duration of gear hauling, and the reservoir's various geographic locations. Seine nets were the most often used fishing gear, and the majority of the catch consisted of Clupeidae. When all gears were combined, the seine net dominated the overall catches (>90 %), showing the dominance of Clupeidae as demonstrated in an earlier study in Kaptai Lake [10]. The decline of predatory and large fish in an aquatic ecosystem can affect the structure of the community, leading to the dominance of smaller species. Our findings were consistent with earlier research demonstrating that small fish dominate aquatic ecosystems whereas large fish have reduced [31]. Cyprinidae was determined to be the most dominant family at Nong Han Lake in Thailand and Chalan Beel in Bangladesh by Rayan et al. [32] and Hossain et al. [33] respectively. Due to changes in geographic location and the type of equipment employed, these results were different from those of the current study. The highest number of species captured by seine net (41), were also reported from other freshwater reservoirs in Bangladesh [34,35]. The fishing gear used by fishermen may vary depending on the water level, bottom condition, current presence, and type of aquatic vegetation [35]. The current analysis revealed that there was no lift net in Kaptai and Naniarchar, and just a push net in Barkal. This trend might be brought on by the small sample size and absence of daily sampling in the current study due to financial restrictions.

4.2. Species selectivity of gears

Despite catching a diverse range of species, each gear was selective and dominated by a small number or single species [14], implying that some gears captured different species while others were quite similar in their selectivity [36]. The dominance of fish captured by seine nets (*C. soborna, G. chapra*) makes them more selective than other fishing nets, suggesting that they may be targeting

Table 5
SIMPER analysis for catch composition based on study sites.

Taxon	Average Dissimilarity					Contribution (%)				
	BK	KT	LG	NC	RG	BK	KT	LG	NC	RG
Bagridae	1.912	4.555	2.953	3.175	1.971	6.30	17.78	13	6.42	11.84
Gobiidae	1.728	3.426	2.31	5.678	1.831	5.7	13.38	10.17	11.49	11
Ambassidae	1.688	3.356	2.12	6.234	1.842	5.563	13.1	9.335	12.61	11.07
Cichlidae	1.686	1.367	1.049	–	0.229	5.557	5.338	4.619	–	1.376
Hemiramphidae	1.682	2.85	1.727	4.311	1.592	5.546	11.12	7.603	8.72	9.566
Palaemonidae	1.634	0.879	1.745	4.311	1.46	5.387	3.431	7.684	8.72	8.777
Belonidae	1.565	–	0.6512	–	0.2045	5.158	–	2.867	–	1.229
Clupeidae	1.54	2.2E-05	1.474	8.02	0.5536	5.077	8.56E-05	6.49	16.22	3.327
Mastacembelidae	1.499	0.879	1.76	7.067	1.142	4.94	3.431	7.75	14.3	6.865
Schilbeidae	1.478	3.53	1.628	1.786	1.795	4.872	13.78	7.168	3.612	10.79
Cobitidae	1.331	–	1.049	–	0.1139	4.387	–	4.619	–	0.6847
Aplocheilidae	1.331	–	–	–	–	4.387	–	–	–	–
Mugilidae	1.219	–	–	–	–	4.019	–	–	–	–
Sisoridae	1.219	–	–	–	0.1139	4.019	–	–	–	0.6847
Heteropneustidae	1.219	–	–	–	0.4259	4.019	–	–	–	2.56
Sciaenidae	1.219	–	–	–	1.434	4.019	–	–	–	8.619
Siluridae	1.134	–	0.6512	–	0.1139	3.739	–	2.867	–	0.6847
Notopteridae	1.134	–	0.6512	–	0.229	3.739	–	2.867	–	1.376
Channidae	1.134	1.367	–	–	–	3.739	5.338	–	–	–
Osphronemidae	1.134	–	0.6512	–	–	3.739	–	2.867	–	–
Badidae	1.134	–	–	–	0.1139	3.739	–	–	–	0.6847
Cyprinidae	0.7149	3.408	2.291	8.853	1.475	2.357	13.3	10.09	17.91	8.863

BK = Barkal; KT = Kaptai; LG = Langadu; NC = Naniarchar; RG = Rangamati sadar.

schooled fish. It is unsurprising to capture high domination of fish taken by seine nets due to their large size and small (0.2–1.8 cm) mesh before being caught by other gears. Furthermore, seine nets are used to collect small pelagic species such as clupeid (*C. soborna, G. chapra*), making it selectively different from others. The dominancy of specific species such as clupeid was also found by Ahmed and Hambrey [9]; Khatun et al. [37] for small meshed seine net in Kaptai lake and McClanahan and Mangi [36] for beach seine net in multi-species fishery of southern Kenya. Push nets also appeared to have the most distinct selectivity for capturing Palaemonidae (*M. lamarrei*) in Kaptai Lake. FAO [38] and Alam et al. [39] observed a similar finding in which push net for shrimps is a fairly prevalent fishing gear. Lift nets and gill nets share much of their selectivity, with *G. chapra*, *A. colia*, *O. cotio*, and *G. giuris* being the most prevalent species of these gears; where *G. chapra* and *A. colia* were dominating in gill nets, whilst *O. cotio* and *G. giuris* were prominent in lift nets. This overlapping might be due to much similar mesh size of gears and the same sampling sites. The similarity of their catch poses challenges in determining their selectivity based on the current data, requiring further investigation due to the potential overlap in captured species.

4.3. Catch per unit effort (CPUE)

Diversity of species is a key ecosystem indicator that represents fishing pressure and system-level resilience [40,41]. The seine net captured the greatest number of species compared to other fishing gears, which enhanced CPUE. Similar to Ahmed and Hambrey [9] in Kaptai Lake; Tikadar et al. [35] in Gorai River; and Hossain et al. [33] in Chalan Beel, Seine net had the greatest CPUE. The catch rate among the sampling locations indicated no significant variances, however, the CPUE for the selective gears used in Kaptai Lake revealed significant differences between them. The mean CPUE of gill net and lift net was lower in the current study than in Ahmed and Hambrey [9] and Tikadar et al. [35]. Several factors may have contributed to these disparities, including the size of the nets, the location of the fishing spots, the number and experience of the fishermen, etc. Other factors could be environmental such as depth of sampling sites, turbidity, waves and rainy season.

Our analysis revealed a positive but weak relationship between CPUE and species richness, whereas Humphries et al. [42] discovered rather substantial positive correlations between CPUE and abundance or density. The nature of this relationship may be influenced by the population stock in certain regions, the quantity of fishing gear employed, and the selection or experience of fishermen [43,44].

4.4. Spatial variations in species composition

Fish community composition varies within different aquatic ecosystems [45]. The current research found a weak spatial variation in fish community composition between gear and sampling sites. In contrast, large spatial variation in fish community composition was observed in Lake Malawi [46] and Tonle Sap Lake in Cambodia [47], while spatial variation in fish community composition was absent in Dianshan Lake in China [48]. This could be attributed to heterogeneous environmental conditions, different geographic locations, the migratory nature of certain fish species, and sampling error variation. The current study found that three sites, Barkal (BK), Langadu (LG), and Kaptai (KT), contributed similar spatial variation in fish community composition due to the most contributing families, which included Bagridae, Gobiidae, and Ambassidae. The SIMPER analysis revealed lift net caused significant dissimilarities among gears because there was no lift net in Kaptai and Naniarchar. Gobiidae were the main contributor of dissimilarities among gears because of the different mesh size of gears. As most of gobiid fish are relatively small, typically less than 10 cm (3.9 inch) in length [49] and caught by small meshed gears. Furthermore, Naniarchar site recorded with highest dissimilarities due to the contribution of Cyprinidae. It might be because high water levels during the study period, and a high number of Cyprinidae fish obtained using large mesh seine nets. Ahmed and Hambrey [9] also mentioned that large mesh seine net as the main tool for harvesting Cyprinidae in Kaptai Lake. In addition, the dissimilarity of dominant species among study sites and gears indicates that fishermen in Kaptai lake employ similar fishing strategies and behaviors. Hydrological and geographic conditions may influence the distinctiveness of species assemblages at these places. Furthermore, the catch composition of lift net, gill net, and push net exhibited a similar ordination pattern, however, the catch composition of seine net revealed a distinct pattern due to the size and design of the net, as well as mesh size variation.

Although species selective gear can reduce bycatch and save a few rare or vulnerable species [50], small mesh-size selective fishing gears can capture endangered and vulnerable species indiscriminately, which is contrary to ideal conservation rules. Furthermore, to achieve sustainable fishing, employ gear with minimal species overlap and catch larger individuals [36]. In Kaptai Lake, small mesh-size selective fishing gear such as seine net (locally known *kechki* net) is used to capture low-priced schooling species (Clupeid), as well as leading to overfishing and a reduction in the abundance of huge, high-value fish and their fingerlings. Jennings et al. [51] found similar results when utilizing highly selective gears on smaller and lower-value fish, indicating a negative impact on the livelihood of artisanal fishers [52]. Previous studies in Kaptai lake indicated that overall catches were lower on fishing grounds where small meshed seine nets, lift nets, and gill nets were employed, and relatively few illegal-sized fish were caught, showing that there was no need to regulate the size of mesh used in this fishery [9]. Many fishermen assert that in addition to collecting small fish, small meshed seine nets have a harmful effect on fish eggs and their larvae. Similarly, current research indicates that small mesh gill nets (current nets) and lift nets can have a negative impact by trapping indigenous species that are too small. Considering the diversity and catchability of species, seine nets were deemed the appropriate gear in the Kaptai reservoir; however, it is widely used to catch illegal-sized clupeid fish as well as may involve capturing eggs/juveniles and species with small size. Also, regarding the adverse impacts of small-mesh seine nets, allowing them in shallow habitats would be unproductive and could lead to the failure of recruitment, especially for Cyprinidae, Bagridae, Schilbeiae, Notopterygii, and Cichlidae species.

There has been little research on fishing effort, gear efficiency, selectivity of various fishing gears, and catch composition in multispecies Kaptai Lake. Furthermore, because of the nature of multi-species fisheries, one or more gears can be used to explore catch composition, diversity, and trophic level interaction by shifting sampling sites and homogeneous catches [36]. On the contrary, over-usage of gear may result in a drop in medium to high-level herbivore species, causing ecological inequity and disrupting the food chain in the aquatic ecosystem [36,53–55]. Gear-based fisheries management [56] is popular in co-management programs due to its simplicity and clear applicability, such as faster detection of gear and less monitoring required, saving local communities and national governments implementation expenses [36,57]. Unfortunately, the lake management authorities have not yet mandated any gear for the Kaptai reservoir, therefore fishermen choose gear and net sizes based on their desire to catch the target species [9]. The selectivity of gear types in this study may vary based on when they are used, fishing expertise, and the habitat they chose [58]. These variables and other fish biometric data, which would have provided a better picture of Kaptai Lake fisheries, were not taken into account in this study due to data-poor fisheries. We examined the gear-based catch composition, CPUE, and spatial distribution pattern, although the data employed in this study was insufficient in terms of sampling each month (fishing is prohibited for fish breeding season) and sample site count. Regardless, this study provides information concerning the current state of artisanal fisheries in Kaptai Lake. To paint a better image of the Kaptai lake fisheries, parameters that were not considered, as well as sampling that should cover all months and places of the year with a suitable sample size, should be suggested. The current study serves as a benchmark for gear-based Kaptai Lake fisheries and can be used to assess the efficacy of future management policies.

Data availability statement

The datasets will be made available on request to the corresponding author.

CRediT authorship contribution statement

B.M. Shahinur Rahman: Supervision, Methodology, Investigation, Conceptualization. **Md Khaled Rahman:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Azhar Ali:** Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Rabina Akther Lima:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation. **Md Lipon Mia:** Writing – review & editing, Investigation. **Yahia Mahmud:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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