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(RESEARCH ARTICLE)

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Diet of the five main fish species found in urban lakes in Yamoussoukro (central cote D'ivoire)

Gnanmien Frédéric Kouakou *, Kouakou Roland Djéné, Yao Quitéloua Francis Kra, Jean-Renaud Allouko and Kotchi Yves Bony

Department of Biodiversity and sustainable Ecosystem Management, Faculty Environment, Jean Lorougnon Guede University of Daloa, Côte d'Ivoire.

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Abstract

This study aims to understand the diet of the main fish species, assess trophic interactions and the structure of the trophic network, and detect ecological changes linked to the eutrophication of urban lakes in order to support sustainable management and conservation strategies for fishery resources. It involved sampling fish species every two months, both day and night, in six urban lakes in the city of Yamoussoukro, from July 2021 to May 2022. This made it possible to determine the food composition of the species *Oreochromis niloticus* (Limnaeus, 1758), *Sarotherodon galilaeus* (Limnaeus, 1758), *Sarotherodon melanotheron* (Rüppell, 1852), *Coptodon zillii* (Gervais, 1848), and *Hemichromis fasciatus* (Peters, 1857), for which at least 30 full stomachs were analyzed, or 887 full stomachs in total. This analysis identified five categories of food resources: phytoplankton, zooplankton, macroinvertebrates, fish, and others. The species *Oreochromis niloticus*, *Sarotherodon galilaeus*, *Sarotherodon melanotheron*, and *Coptodon zillii* exploit the same food resources and are planktivorous. *Hemichromis fasciatus*, on the other hand, is more carnivorous. Knowledge of these diets makes it possible to establish the food web patterns of fish in the various urban lakes of Yamoussoukro and to guide local communities in the management and conservation of these aquatic environments.

Keywords: Urban Lakes; Diet; Planktivore; Prey; Yamoussoukro

1 Introduction

The urban lakes of Yamoussoukro, although artificial, play a crucial ecological and socio-economic role [1]. They are home to a variety of fish, including several species of Cichlidae that are emblematic of West Africa. According to [2], the fish caught in these lakes constitute an affordable food resource for the city's population. However, these bodies of water are subject to increasing anthropogenic pressures (urbanization, habitat modification, domestic waste and pesticide discharge), [3]. This situation could pose a threat to fish and even a health risk to populations who consume fish from these urban lakes. In this context, understanding the diets of dominant species is essential, first to assess trophic interactions and food web structure, then to detect ecological changes related to eutrophication, and finally to support sustainable management and conservation strategies for fishery resources. Indeed, knowledge of the diets of fish fauna is very important for a better understanding of the interactions between different fish species themselves and between them and other aquatic organisms, as well as their environment [4]. This approach will provide information on predators, prey, other food resources for fish, and the trophic potential of these lakes [5]. It also allows us to assess the importance and role of each prey species in the food web [6]. Similarly, the food preferences of fish are important data for conservation and sustainable management strategies for these aquatic environments [7]. In this study, we focus on *Oreochromis niloticus* (Limnaeus, 1758), *Sarotherodon galilaeus* (Limnaeus, 1758), *Sarotherodon melanotheron* (Rüppell, 1852), *Coptodon zillii* (Gervais, 1848), and *Hemichromis fasciatus* (Peters, 1857), five species representative of the urban lakes of Yamoussoukro, in order to analyze their diets in relation to available resources, anthropogenic

* Corresponding author: Gnanmien Frédéric Kouakou

pressures, and the ecological characteristics of the environment. The approach adopted is based on direct observations, stomach content analyses, and cross-referencing with local environmental data, with the aim of better understanding the ecological roles played by these species within their habitat.

2 Material and methods

2.1 Study environment

Yamoussoukro is located between 6°48' and 6°52' north latitude and between 5°12' and 5°18' west longitude **[1]**. This city is characterized by a dry season that lasts from November to February and a rainy season from March to October (Figure). Annual rainfall varies between 900 and 1600 mm. The average annual temperature is around 26°C **[1]**. The district of Yamoussoukro has thirty-one (31) natural and artificial lakes, including ten (10) developed lakes in the city of Yamoussoukro **[3]**. For this study, six (6) of these 10 lakes were selected for exploration. This choice was made based on their accessibility throughout the year, their geographical location, and the anthropogenic activities carried out in the surrounding area. A coding system was adopted to name these lakes. The lakes located in the city center have the codes L1, L2, and L3. Those located at the eastern, western, and southern ends have the codes L4, L5, and L6, respectively.

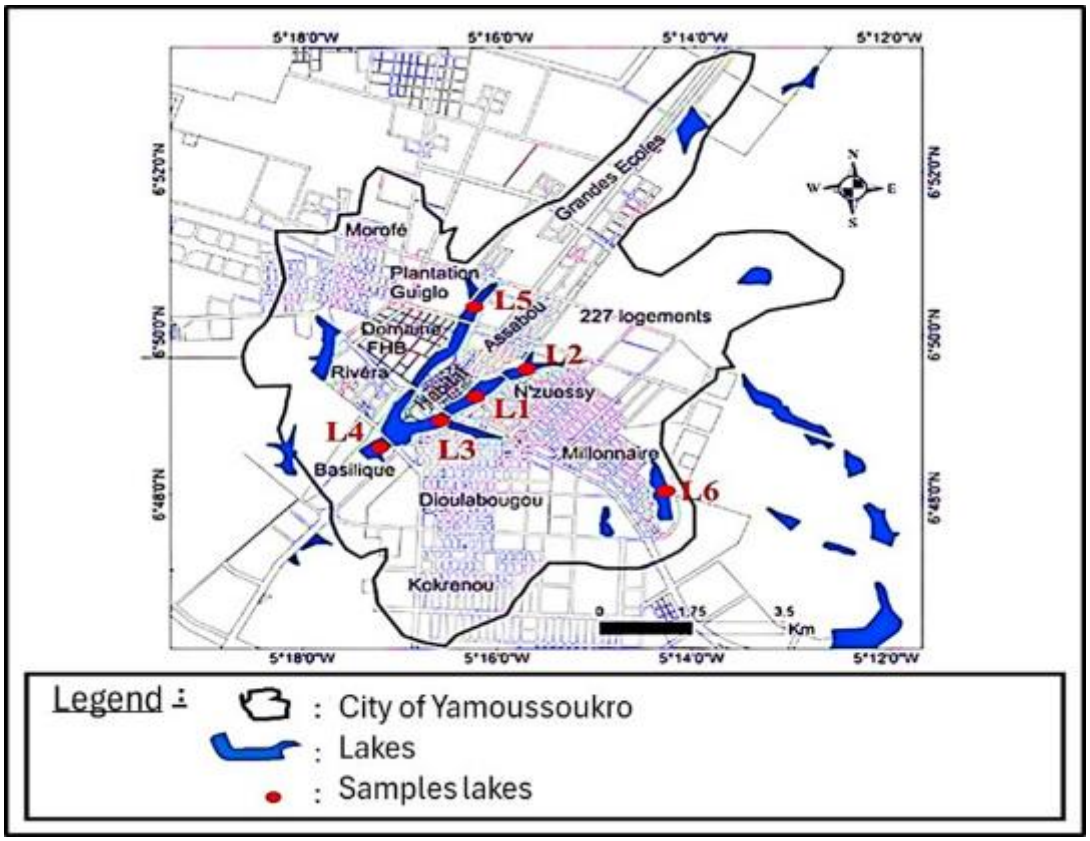

Figure 1 Location of the six urban lakes sampled in the city of Yamoussoukro

2.2 Sampling and analysis of fish stomach contents

Fish fauna was sampled using cast nets and gillnets with mesh sizes of 10, 15, 20, and 25 mm. For night fishing, sampling consisted of setting the gillnets between 4 p.m. and 5 p.m. and retrieving them the next day between 6 a.m. and 7 a.m. For daytime fishing, these nets were set between 7 a.m. and 8 a.m. and then retrieved between 3 p.m. and 4 p.m. The identification of the fish fauna was made possible using the keys proposed by [8; 9; 10; 11]. Each fish was then gutted and the stomach removed and stored in labeled pill boxes containing 5% formalin. The stomach was opened and its contents weighed [12]. The contents were then diluted in a 5 mL graduated cylinder containing water, where the volume of each stomach content was determined by the displacement of the water level. The stomach envelope was also weighed. The stomach contents were filtered through a series of sieves with diameters of 1000, 500, and 100 µm. The fractions retained on the sieves and the filtrate were examined under a binocular magnifying glass and a microscope,

respectively. The prey categories were sorted, counted, and weighed to the nearest 0.001 g. Large prey were sorted and identified with the naked eye in Petri dishes [13].

The fish species included in this study are those for which at least 30 full stomachs were analyzed.

2.3 Expression of fish feeding methods and indices

2.3.1 Percentage occurrence (Fc) of prey

The corrected percentage occurrence (*Fc*) is the percentage ratio of the frequency of prey i to the sum of the frequencies of prey i [14]. The corrected occurrence percentage (Fc) is calculated using the following formula:

$$\boldsymbol{F_c = \frac{F_i}{\Sigma F_i} \times 100}$$

Where: *Fi* = *ni/nt* = Frequency of prey *i*; *ni* = Number of stomachs containing prey i; *nt* = Total number of full stomachs examined.

The classification by **[15]** was used to determine the categories of prey:

- *Fc* ≥ 80%: very frequent prey;
- 60% ≤ *Fc* < 80%: frequent prey;
- 40% ≤ *Fc* < 60% = fairly frequent prey;
- 20% ≤ *Fc* < 40%: incidental prey;
- *Fc* < 20%: accidental prey.

2.3.2 Weight percentage (P)

The weight percentage (*P*) is used to estimate the relative importance of each item category **[16]**. It is the percentage ratio of the total weight of individuals in the same prey category of a taxonomic group (species, family, or order) to the total weight of the prey inventoried **[16]**. It is calculated using the following formula:

$$\boldsymbol{P = \frac{P_i}{P_t} \times 100}$$

Where: *Pi* = Total weight of individuals in the same prey category i; Pt = Total weight of prey inventoried.

2.3.3 Prevalence index (Ip)

The prevalence index (Ip) developed by **[17]** and modified by **[18]** gives the relative importance of a category of prey identified in a fish's diet. It is obtained by combining the occurrence (Fc) and weight (P) percentages. This involves calculating the percentage ratio of the product of the occurrence and weight percentages to the sum of the products of the occurrence and weight percentages. It is expressed as follows:

$$\boldsymbol{Ip = \frac{(F_c \times P)}{\Sigma\,(F_c \times P)} \times 100}$$

The preponderance index (*Ip*) varies between 0 and 100. Based on the value of the preponderance index (*Ip*), **[18]** define four categories of prey:
- Ip < 10 = Incidental prey;
- 10 ≤ Ip ≤ 25 = Secondary prey;
- 25 < Ip ≤ 50 = Important prey;
- Ip > 50 = Primary prey.

2.3.4 Food overlap index (Cλ)

The Morisita-Horn food overlap index (*Cλ*), also known as the simplified Morisita index, was used to gauge the similarity of the food ingested by different fish species in the lakes of Yamoussoukro **[19]**. The food overlap index (*Cλ*) is twice the quotient of the product of the proportions *(Ip*) of prey *i* consumed by species x and y divided by the sum of the squares of the proportions *(Ip)* of prey *i* consumed by species x and y. The food overlap index is calculated using the following formula:

$$C\lambda = \mathbf{2}\frac{\sum_{i=1}^{S} \boldsymbol{X_i Y_i}}{\sum_{i=1}^{S} \boldsymbol{x_I^2} + \sum_{i=1}^{S} \boldsymbol{y_I^2}}$$

Where: s = Total number of prey; xi = Proportion (Ip) of prey i consumed by species x; yi = Proportion (Ip) of prey i consumed by species y.
The diets of organisms overlap significantly when Cλ is greater than or equal to 0.6 [20].

3 Results and discussion

3.1 Overall specific composition of the ichthyofauna

Sampling of 1032 fish identified 14 species (Table 1) grouped into 4 orders, 6 families, and 1 class (Actinopterygii). Among the orders encountered, the order Perciformes, with 2 families and 8 species, is the most diverse. Within this order, the Cichlidae family is the richest in species (7 species). The Perciformes order is followed by the Siluriformes order, which has 4 species. The least species-rich orders are the Characiformes and Osteoglossiformes, each with 1 species.

The inventory of fish in the urban lakes of Yamoussoukro identified 14 species grouped into four orders, six families, and one class (Actinopterygii). This species richness is lower than that reported by **[21]**, who inventoried 36 species in Lake Kossou, which is located in the same Bandama River watershed. This difference in the number of species is likely due, firstly, to the size of Lake Kossou and its location in a rural area, thus less exposed to human activity. Secondly, it may be related to the sampling method used. Two capture approaches were employed: experimental fishing (electrofishing, gillnet fishing, and trap fishing) and artisanal fishing.

The Cichlidae family (Perciformes), with seven (7) species, is the most diverse. This result corroborates that of **[7]**, who showed that the creation of lakes is often accompanied by the colonization of species from the Cichlidae family. According to **[22]**, Cichlids are one of the most taxon-rich fish families in all the world's river basins. This family exploits almost all the food resources available in aquatic environments. This adaptability allows them to occupy a wide range of ecological niches.

Table 1 Specific compositions and occurrences of the fish fauna in the urban lakes of Yamoussoukro (Côte d'Ivoire) from July 2021 to May 2022

Orders	Families	Species	Codes	Lake 1	Lake 2	Lake 3	Lake 4	Lake 5	Lake 6
Characiformes	Hepsetidae	*Hepsetus odoe*	Hod	-	-	-	-	-	**
Ostéoglossiformes	Ostéoglossidae	*Heterotis niloticus*	Hni	-	-	-	**	-	*
Perciformes	Channidae	*Parachanna obscura*	Pob	-	-	-	-	-	***
	Cichlidae	*Coptodon guineensis*	Cgu	-	-	-	-	-	*
		Coptodon hybride	Chy	-	-	-	-	-	***
		Coptodon zillii	Czi	**	*	***	***	**	***
		Hemichromis fasciatus	Hfa	**	***	-	-	**	-
		Oreochromis niloticus	Oni	***	***	***	***	***	***
		Sarotherodon galilaeus	Sga	-	-	-	-	***	**
		Sarotherodon melanotheron	Sme	-	-	-	-	*	-

Siluriformes	Clariidae	*Clarias anguillaris*	Can	-	-	*	-	-	***
		Clarias gariepinus	Cga	-	-	-	-	-	**
	Claroteidae	*Chrysichthys maurus*	Cma	-	-	-	-	-	**
		Chrysichthys nigrodigitatus	Cni	-	-	-	-	-	**
4	**6**	**14**		**3**	**3**	**3**	**3**	**5**	**12**

3.2 Composition of prey consumed by fish

In this study, 887 full stomachs were examined. For *Sarotherodon melanotheron*, 30 full stomachs were examined; for *Sarotherodon galilaeus*, 68 full stomachs; for *Hemichromis fasciatus*, 81 full stomachs; for *Coptodon zillii*, 84 full stomachs; and for *Oreochromis niloticus*, 624 full stomachs were examined. The composition of the stomach contents of the five fish species is shown in Table 2. The analysis reveals five categories of prey: phytoplankton, zooplankton, macroinvertebrates, fish, and others. Phytoplankton consists of Dinophytes, Cyanophytes, Euglenophytes, and Chlorophytes. Zooplankton consists of rotifers, Copepods, Cladocerans, and Ostracods. Macroinvertebrates are represented by Arachnids, Clitellates, and Mollusks (bivalves and gastropods). Fish are represented by fry. The "other" category includes macrophytes, which are represented by leaf and wood fragments, seeds, fruits, and plant debris. *Coptodon zillii*, *Oreochromis niloticus*, and *Sarotherodon galilaeus* have a diet rich in aquatic macroinvertebrates, phytoplankton, zooplankton, and macrophytes, unlike *Hemichromis fasciatus* and *Sarotherodon melanotheron*. On the other hand, fry are part of the diet of *Hemichromis fasciatus*. Analysis of these diets shows the dominance of planktivorous species in the urban lakes of Yamoussoukro. This observation contrasts with that made by **[23]**, who showed the dominance of omnivorous species in small dams in northern Côte d'Ivoire.

Table 2 Different prey identified in the stomach contents of the five fish species dissected and examined in the urban lakes of Yamoussoukro (Côte d'Ivoire) from July 2021 to May 2022**.**

	Stomach contents													
	Phyto.				**Zoo.**				**Macroinvert.**				**Fish**	**Ot.**
Species/Prey	**Di**	**Cy**	**Eu**	**Ch**	**Ro**	**Co**	**Cl**	**Os**	**Ar**	**Cli**	**Mo**	**Ins**	**Al**	**Ma**
Coptodon zillii	+	+	+	+	+	+	+	+	+	+	-	+	-	+
Hemichromis fasciatus	+	+	-	-	+	+	+	-	-	-	+	-	+	-
Oreochromis niloticus	+	+	+	+	+	+	+	+	+	+	+	+	-	+
Sarotherodon galilaeus	+	+	+	+	+	+	+	+	-	+	-	+	-	+
Sarotherodon melanotheron	+	+	-	-	+	+	+	-	-	+	-	-	-	+

Phyto = phytoplankton; Zoo = zooplankton; Macroinvert = macroinvertebrates; Fish = fish; Ot = other; + = Presence of prey; _ = Absence of prey

3.3 Occurrence and Prevalence of prey in diets

Table 3 shows the frequency of occurrence and the importance of prey in the diets of the five fish species examined. Phytoplankton is a frequent prey for *Oreochromis niloticus* (Fc = 76%), *Coptodon zillii* (F = 65.2%), *Sarotherodon galilaeus* (Fc = 78.4%), and *Sarotherodon melanotheron* (F = 70.3%), and an incidental prey for *Hemichromis fasciatus* (Fc = 17.1%). Zooplankton is an accessory prey for *Coptodon zillii* (Fc = 20.4%) and accidental prey for *Oreochromis niloticus* (13.9%), *Sarotherodon galilaeus* (Fc = 18.4%), *Sarotherodon melanotheron* (Fc = 13%), and *Hemichromis*

fasciatus (Fc = 9.3%). Aquatic macroinvertebrates are accidental prey for all species studied. The same is true for macrophytes.

Phytoplankton is the main food source for *Oreochromis niloticus* (IP = 74.9%), *Sarotherodon galilaeus* (PI = 70%), *Sarotherodon melanotheron* (PI = 70%) and *Coptodon zillii* (PI = 44.4%). In contrast, it is a secondary food resource for *Hemichromis fasciatus* (PI = 2.7%). Zooplankton is an important prey for *Coptodon zillii* (PI = 30%), secondary for *Oreochromis niloticus* (PI = 19.1%), *Sarotherodon galilaeus* (PI = 17%), *Sarotherodon melanotheron* (PI = 15.7%) and *Hemichromis fasciatus* (PI = 10%). Macroinvertebrates are secondary prey for *Sarotherodon galilaeus* (PI = 11.3%) and *Sarotherodon melanotheron* (PI = 13.2%). They are incidental prey for *Oreochromis niloticus* (PI = 0.9%), *Coptodon zillii* (PI = 5.6%) and *Hemichromis fasciatus* (PI = 2.3%). Analysis of the percentages obtained shows that fish are the main prey of *Hemichromis fasciatus* (PI = 85%). Plant debris (macrophytes) are incidental prey for all five (5) fish species.

Analysis of the stomach contents of fish species shows that *Coptodon zillii, Oreochromis niloticus, Sarotherodon melanotheron*, and *Sarotherodon galilaeus* have a more diverse diet than *Hemichromis fasciatus*. According to [24], these species feed on whatever they find in their environment and their diets may change from one aquatic environment to another or from one season to another. As for *Hemichromis fasciatus*, our data indicate that this species feeds mainly on fish. This result is similar to the work of [25] in the aquatic systems of the coastal zone in southern Côte d'Ivoire, where this author also showed that this species is piscivorous.

The low proportions of aquatic macroinvertebrates in the stomach contents of fish are thought to be due to the abundance of macrophytes in these lakes. Indeed, the massive presence of these plants would constitute microhabitats for these macroinvertebrates. These microhabitats serve as hiding places, thus protecting them from predators [26].

Table 3 Occurrences of prey (% F) and Prevalence Indices (% Ip) of prey consumed by the five species of fish dissected and examined in the urban lakes of Yamoussoukro (Ivory Coast) from July 2021 to May 2022.

Species/ Preys	**Phytoplankton**			**Zooplankton**			**Macroinvertebrates**			**Fish**			**Other**		
	FC	P	*IP*	*FC*	P	*IP*	*FC*	P	*IP*	FC	P	*IP*	FC	P	*IP*
Coptodon zillii	65.2	19.2	60	20.4	70.3	30	2.4	0.7	5.6	0	0	0	12	10	4.4
Hemichromis fasciatus	17.1	4.18	3	9.3	16.4	10	4.7	0.3	2.3	69	80	85	0	0	2.3
Oreochromis niloticus	76	29.3	75	13.9	68.5	19.1	5.4	0.6	1.9	0	0	0	4.7	2	4.1
Sarotherodon galilaeus	78.4	46.7	70	18.4	40	17	0.1	12.4	11.3	0	0	0	3.1	1	1.7
Sarotherodon melanotheron	70.3	52	70	13	46.2	15.7	14.5	0.2	13.2	0	0	0	2.2	2	1.1

3.4 Dietary overlap among fish

Table 4 shows the dietary overlap index (Cλ) values for the diets of the five species examined in the Yamoussoukro lakes. The dietary overlap index (Cλ) values calculated from the preponderance index values (see Table 3) are all greater than 0. The diets of the species are highly significant for the pairs:

- *Coptodon zillii* and *Oreochromis niloticus* (0.85), *Coptodon zillii* and *Sarotherodon galilaeus* (0.77), *Coptodon zillii* and *Sarotherodon melanotheron* (0.72). The main shared resource is phytoplankton (Dinoflagellates, Cyanobacteria, Euglenophytes, and Chlorophyta), and the secondary resource is zooplankton (Rotifera, Copepoda, and Cladocera);
- *Oreochromis niloticus* and *Sarotherodon galilaeus* (1), *Oreochromis niloticus* and *Sarotherodon melanotheron* (0.98). The main shared resource is phytoplankton (Dinophyceae, Cyanobacteria, and Euglenophyceae), and the secondary resource is zooplankton (Rotifera, Copepoda, and Cladocera).
- *Sarotherodon galilaeus* and *Sarotherodon melanotheron* (1). The main shared resource is phytoplankton (Dinophyceae and Cyanobacteria) and the secondary resource is zooplankton (Rotifera, Copepoda, and Cladocera).

Calculations of the food overlap index values between the five fish species in the urban lakes of Yamoussoukro indicate significant overlap (Cλ > 0) for the acquisition of phytoplankton and zooplankton. This observation reflects strong competition between these species for these resources **[27]** notes that when two species exploit the same resources,

one eventually excludes the other. This could explain the low diversity of fish fauna in these lakes. The strong predominance of plankton feeders in the urban lakes of Yamoussoukro is thought to be linked to the abundance of phytoplankton resources.

Table 4 Diet overlap indices (Cλ) of the diets of the five fish species dissected and examined in the urban lakes of Yamoussoukro (Ivory Coast) from July 2021 to May 2022.

	Czi	**Hfa**	**Oni**	**Sga**
Czi				
Hfa	0.11			
Oni	0.85	0.07		
Sga	0.77	0.06	1	
Sme	0.72	0.05	0.98	1

Significant values are in bold, Hfa = Hemichromis fasciatus, Czi = Coptodon zillii, Oni = Oreochromis niloticus, Sga = Sarotherodon galilaeus, and Sme = Sarotherodon melanotheron, significant values are in bold.

4 Conclusion

This study highlights the functional diversity of the five main fish species in the urban lakes of Yamoussoukro. The results show that urban pressures, eutrophication, and changes to natural habitats are disrupting the organization of these aquatic environments. These five species occupy the same trophic niches, causing ecological imbalance in the lakes studied. The species *Oreochromis niloticus, Sarotherodon galilaeus, Sarotherodon melanotheron*, and *Coptodon zillii* are planktivorous. *Hemichromis fasciatus*, on the other hand, is more of a predatory species. The results provide a solid scientific basis for guiding responsible development policies, supporting local food security, and stimulating collective ecological awareness. Thus, this research contributes not only to the preservation of urban biodiversity, but also to the emergence of communities that are more resilient to environmental pressures.

In an era marked by ecological upheaval and rapid urbanization, it reaffirms that science, when rooted in the field and driven by an integrated vision, can become a powerful tool for social transformation.

Compliance with ethical standards

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Disclosure of Conflict of interest

No conflict of interest to be disclosed.

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