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Research Article

Fish assemblage composition and fishery production in the man-made lake, West Africa

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ABSTRACT

This study aims to update the composition and the fishery production of the lake Ayamé 1.The fish were sampled from July 2017 to June 2018 with gillnets, traps, hawks, longlines, bamboo traps and seines. 9959 fish belonging to 37 species distributed between 14 families and 6 orders were during this study for a biomass of 606.002 kg. The best represented families are cichlids (8 species), followed by Mormyridae (6 species) and Alestidae (5 species). Regarding species, 7 species are best represented. This population is dominated by small individuals (81.41%).The fishing effort deployed by fishermen is 5374 trips, a production of 723488 kg or 723.49 t. The gillnet (56.76 %) is the most used fishing gears in the lake. The threat to this lake is the collapse of its fish fauna that would be subject to renewed conflict.

INTRODUCTION

Fishing is an anthropogenic activity aimed at harvesting living aquatic resources. It poses a threat to fish fauna when it affects the dynamics of stocks and fish assemblage (Worm and Duffy, 2003). According to FAO (2008), the importance of fisheries resources makes fisheries an essential component of the economic and social development of coastal countries. However, the fish sector faces multiple constraints, the most important of which are related to the status of the resource (FAO, 2008). In addition, a high exploitation of resources leads to a decrease in the productivity of certain fisheries (UEMOA, 2007). This has led to conservation and rational management measures for fish stocks and fisheries. And this requires knowledge of the diversity, abundance and distribution of fish species in the reservoirs in order to develop management and conservation programs (Hashemi *et al.*, 2015).

This concern has long been a concern for fisheries managers and the scientific community (Tah, 2012). To overcome this concern, several studies have been carried out on the fish assemblage (Kouamélan *et al.*, 2003; Kamelan *et al.*, 2013a; b) in the continental environment and in particular on the hydroelectric dam lakes. This is the case of the dam of Ayamé 1 (Tah *et al.*, 2009, Ouattara *et al.*, 2010; Nobah *et al.*, 2014) and the Ayamé 2 dam lake (Adou *et al.*, 2017). Indeed, Lake Ayamé 1, which is one of the bases of the continental fishery, was closed to fishing with the expulsion in 1998 for two years following a conflict between native and non-native fishermen. Conflict caused by the depletion and scarcity of fish resources in the lake (Vanga, 2001). Thus, the work of Tah (2012) carried out between 2004 and 2005 assessing the level of stocks of fish communities of this lake after the departure of the allogenic fishermen confirmed a return to normal. But since the return of non-native fishermen to Lake Ayamé 1, no study has been conducted to assess the state of the lake's stocks and the diversity of its fish.

This work aims to characterize the fish assemblage of the lake, with a view to contributing to the rational and sustainable management of exploited resources in order to avoid other possible fisheries conflicts.

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MATERIALS AND METHODS

Study Area

Located south-east of Côte d'Ivoire between longitudes 3 and 3.5 ° West and latitudes 5.3 and 6 ° North, Lake Ayamé 1 (Fig. 1) is built on the Bia River, since 1959 (Tah, 2012) on 9320 ha, 80 km long and 27 km wide with a maximum depth of 30 m (Ouattara, 2004). This body of water created by the Ayamé 1 dam has become the first true center of inland fisheries in Côte d'Ivoire (Tah, 2012). The lake benefits an Attiean climate with 4 seasons (2 dry seasons and 2 seasons of rain) (Savané and Konaré, 2010). The variations in the level of Ayamé 1 Lake are related to the flow of the Bia River and the turbine.

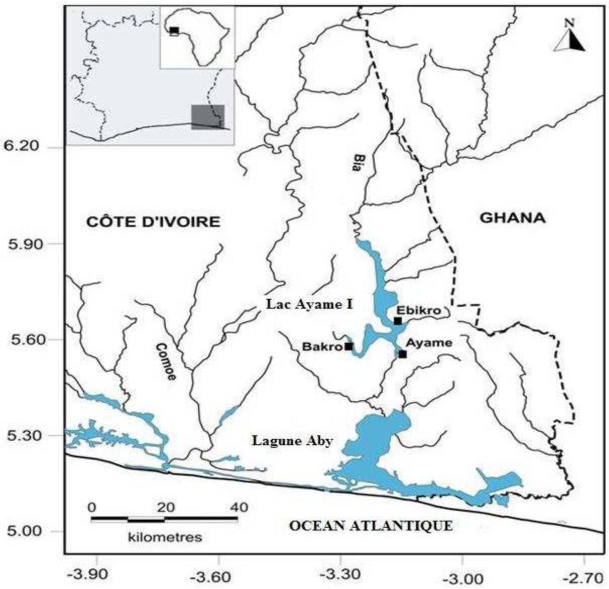

Fig 1: Location of the Ayamé 1 reservoir and location of sampled stations (Tah, 2012)

Fish sampling

Sampling was conducted from July 2017 to June 2018. The fish were sampled monthly from experimental and commercial catches made at the Ayamé, Bakro and Ebikro landings. In the experimental fishery, a battery of 11 gillnets (10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60) was used for sampling. The nets were laid in the evening at 17h and picked up the next day at 7 am then put again and revisited at 12h. For commercial fishing gillnets, traps, baited and non-baited longlines, bamboo traps, hawks and dam nets were used for catching fish. The fish were identified using the identification keys of Paugy *et al*. (2003a; b). They were measured and weighed respectively with an ichthy meter (to the nearest mm) and a SATUROS brand electronic balance of precision 0.01 g.

Production statistics

Production

The fish production statistics take into account the total catch per fishing gear (in kg). These data were used to calculate the monthly quantities (in kg) of fish caught in the different zones. The sum of the monthly quantities makes it possible to calculate the total quantity of fish caught by the fishermen in each zone (Koné, 2012).

Fishing effort

The fishing effort considered in this study is the set of daily fishing trips for all gear actually involved in catching fish. In order to determine the actual fishing pressure per fishing area, the number of fishing trips, per month for each fishing unit, was evaluated for each station. These data made it possible to calculate the fishing effort.

Fishing gear utilization rate

The fishing gear utilization rate (Tu) was calculated during this study. This is the number of trips using a given gear type (Npe), relative to the total number of trips recorded in the year (Npt). The formula used is that proposed by Tah (2012).

$Tu = (Npe / Npt) \times 100$

The gear or groups of fishing gear considered in this study are nets, traps, longlines, bamboo traps, seines and hawks.

Data analysis

To understand the organization of the fish assemblage of the Ayamé 1 reservoir, the data were analyzed using different indices calculated according to the following formulas.

Percentage of occurrence: $F = Fi \times 100 / Ft$ with Fi = number of trips during which the species appears in the catch, Ft = total number of monthly trips.

Percentage: $N = Ni \times 100 / Nt$ with Ni = number of individuals of a species occurring in the catches, Nt = total number of individuals in the catches.

Percentage weight: $W = Wi \times 100 / Wt$ with Wi = weight of individuals of a species occurring in the catches, Nt = total number of individuals in the catches.

Shannon Diversity Index (H '): $H' = -\Sigma pi \log_2 pi$ with pi = ni / N, where N is the sum total of the numbers (individuals) obtained for all species; nor, the number of individuals per species; pi the relative abundance of species i in the sample.

Equitability (E): $E = H' / \log_2 S$, with E between 0 and 1. S is the specific richness.

Sturge rule

To characterize the size structure of the fish community of Lake Ayame 1, the Sturge rule, as used by Kouamélan et al. (2000), was used to determine the different size classes.

$NC = 1 + (3.3 \times \log_{10} N)$ with NC: Number of classes, N: total number of specimens examined.$I = 1 + ((SLmax-SLmin)) / (N.C)$ With I: class interval, SL: standard length. This allowed to determine the dominant sizes in the catches. Numerical (density) and weight (biomass) abundances were also calculated monthly for the community.

Statistical analysis

Seasonal variations in species richness, density, and biomass are compared using the Man-Whitney test, and the Kruskal-Wallis test was used to compare variations in the Shannon (H ') and equitability of Piélou (E)

RESULTS AND DISCUSSION

Specific richness

On the whole, 37 species from 26 genera, 14 families and 6 orders were collected in the sampling sites (Table 1). Two species marine/or brackish water species (*S. melanotheron*, *T. guineensis*,), two introduced species (*H. niloticus* and *O. niloticus*) and a hybrid species (*T. zillii x T. guineensis*). This species richness is lower than that obtained by Tah *et al.* (2009) in the same lake. The absence of some species in our data could be related to the sampling method and the different habitats exploited. Indeed the capture of some small species requires the use of electric fishing. Unfortunately this method is difficult to implement in deep environments such as Lake Ayamé 1. Moreover Siluriforms and Perciforms are the most diversified orders, with respectively 5 families and 10 species and 3 families and 10 species. The most diverse family in this study is Cichlidae (8 species). This same observation is made by Adou *et al.* (2017), Ouedraogo *et al.* (2015), Montchowui *et al.* (2008) and Balogun (2005), respectively in the lakes of Ayamé 2 (Ivory Coast), Sahelian of Higa (Burkina Faso), Hlan (Benin) and Kangimi (Nigeria). Indeed, the dominance of this family in the catches is due on the one hand to the environmental preferences of these species (Solomon *et al.*, 2017) and on the other hand to their prolific reproduction which allows them to easily inhabit the water bodies especially where predation is least abundant (Ikpi and Okey, 2010). Fish assemblage does not vary from one season to another (Mann-Whitney test, $p > 0.05$). Thus, a total of 34 species were captured during the great dry season, 31 species during the great rainy season, as well as during the short dry season and the short rainy season (Fig. 2).

Table 1: List of fish sampled from July 2017 to June 2018 in Ayamé 1 Dam Lake

Orders and families	Species	Codes
Osteoglossiforms		
Arapaimidae	*Heterotis niloticus*[b] (Cuvier, 1819)	*Hnil*
Mormyridae	*Brienomyrus brachyistus* Gill (1 862)	*Bbra*
	Marcusenius furcidens (Pellegrin, 1920)	*Mfur*
	Marcusenius ussheri (Günther, 1867)	*Muss*
	Mormyrus rume Valenciennes, 1846	*Mrum*
	Mormyrops anguilloïdes (Linaeus, 1758)	*Mang*
	Petrocephalus bovei (Valenciennes, 1846)	*Pbov*
Characiforms		
Alestidae	*Brycinus imberi* (Peters, 1852)	*Bimb*
	Brycinus longipinnis (Günther, 1864)	*Blon*
	Brycinus nurse (Rüppel, 1832)	*Bnur*
	Brycinus macrolepidotus Valenciennes, 1849	*Bmac*
	Micralestes occidentalis Gunther, 1899	*Mocc*
Hepsetidae	*Hepsetus odoe* (Bloch, 1794)	*Hodo*
Cypriniforms		
Cyprinidae	*Barbus ablades* Bleeker (1863)	*Babl*
	Barbus sp	*Bspp*
	Labeo parvus Boulenger, 1902	*Lpa*
Siluriforms		
Claroteidae	*Chrysichthys nigrodigitatus* (Lacèpède, 1803)	*Cnig*
	Chrysichthys maurus (Valenciennes, 1839)	*Cmau*
	Chrysichthys sp	*Cspp*
Schilbeidae	*Schilbe mandibularis* (Günther, 1867)	*Sman*
Clariidae	*Clarias anguillaris* (Linaeus, 1822)	*Cang*
	Heterobranchus longifilis (Valenciennes, 1840)	*Hlon*
	Heterobranchus isopterus Bleeker, 1863	*Hiso*
Mokochidae	*Synodontis schall* (Bloch et Schneider, 1801)	*Ssch*
	Synodontis bastiani Daget, 1948	*Sbas*
Malapteruridae	*Malapterurus electricus* (Gmelin, 1789)	*Mele*
Perciforms		
Chanidae	*Parachanna obscura* (Günther, 1861)	*Pobs*
Cichlidae	*Chromidotilapia guntheri* (Sauvage, 1882)	*Cgun*
	Hemichromis bimaculatus Gill, 1862	*Hbim*
	Hemichromis fasciatus Peters, 1852	*Hfas*
	Oreochromis niloticus[b](Linnaeus, 1758)	*Onil*
	Sarotherodon melanotheron[a] *Rüppel, 1852*	*Smel*
	Tilapia guineensis[a](Günther, 1862)	*Tgui*
	Tilapia zillii (Gervais, 1848)	*Czil*
	Tilapia zillii x T. guineensis[c]	*Cztg*
Anabantidae	*Ctenopoma petherici* Günther, 1864	*Cpet*
Synbranchiforms		
Mastacembelidae	*Mastacembelus nigromarginatus* Boulenger, 1898	*Mnig*

[a]fishes with marine and/or brackish water affinities, [b]introduced species and [c]hybrid species

Quantitative aspect of fish composition

A total of 9959 individuals were sampled during this study. The Perciforms (34.63%), the Characiforms (38.65%) and the Siluriforms (19.93%) are the main orders of the lake of Ayamé 1. The other orders make 6.79% of this population. The most abundant families are Alestidae (36.61%) and Cichlidae (34.19%). The most abundant families are Alestidae (36.61%) and Cichlidae (34.19%). Then comes that of Claroteidae (13.43%). The other families (15.77) complete this fish assemblage. The majority species are *B. macrolepidotus* (16.19%) and *S. melanotheron* (12.41%). These results are in agreement with that of Baijot *et al.* (1994), which indicates the dominance of more than one species in small lakes in Burkina Faso.

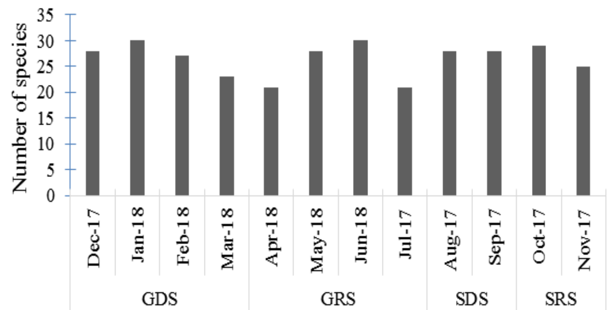

Fig 2: Seasonal variation in species richness from July 2017 to June 2018; GDS: great dry season, GRS: great rainy season, SDS: small dry season, SRS: small rainy season

However, by referring only to catches from the commercial fishery, *S. melanotheron* is numerically the most abundant species. Indeed, the dominance of this species in commercial fisheries catches is linked to the economic interest it represents for the population of this region. In addition, analysis of the seasonal variation of the lake population shows that the highest value of numerical abundance is obtained during the great dry season, ie 4104 individuals and the lowest value during the short rainy season (830 individuals). These different variations in numerical abundance between seasons thus show a significant difference (p <0.05). This variation can be explained on the one hand by the change of behavior of certain species during the different seasons which makes them vulnerable or not to the fishing gear (Bouchereau, 1997) and on the other hand by the rise of the water level favoring thus the migration of fish to flood zones, which are suitable sites for spawning (Bédia *et al.*, 2017). In addition the presence of species such as *B. macrolepidotus*, *C. nigrodigitatus*, *B. longipinnis*, *B. imberi*, *T. zillii* × *T. guineensis*, *T. zillii* and *S. melanotheron* is remarkable throughout the year with significant numerical abundances (Table 2). This remarkable presence of these species during all seasons indicates that this lake offers favorable ecological conditions for their maintenance.

Patterns of fish assemblage

The calculated Shannon-Weaver diversity and equitability indices have respective average values of H '= 2.80 bits / ind and E = 0.78. These values vary from one season to another. The following values (H '= 2.61 bits / ind, E = 0.74) are recorded during the great dry season, (H' = 2.85 bits / ind, E = 0.83) rains, (H '= 2.60 bits / ind, E = 0.76) during the short dry season and (H' = 2.74 bits / ind, E = 0.80) during the short rainy season. The seasonal variation of these indices shows a significant difference (p <0.05). These different values show a good organization of the fish assemblage of the dam of Ayamé 1. Thus the high value of Shannon-Weaver is explained by the presence of a large number of species in the catches. By account the low value of equitability (E <1) can be explained by the dominance of certain species in the fish assemblage.

Table 2: Seasonal variation in the numerical percentage of the main fish species sampled at the Ayamé 1 Dam from July 2017 to June 2018

Species	GDS	GRS	SDS	SRS
B. imberi	11.37	7.96	5.81	3.61
B. longipinnis	4.93	9.42	24.72	6.26
B. macrolepidotus	21.27	12.93	12.43	11.32
C. nigrodigitatus	9.88	11.19	13.61	13.61
S. melanotheron	15.30	10.15	8.09	15.30
T. zillii	6.42	7.40	8.02	5.42
T. zillii x T. guineensis	5.10	8.47	9.86	11.93
Total	74.27	67.52	82.54	67.45

GDS: great dry season, GRS: great rainy season, SDS: small dry season, SRS: small rainy season

Biomass of fish communities

A biomass of 606.002 kg of fish was collected. The orders best represented are, respectively, the perciforms (42.71%), the Siluriforms (29.02%), the Osteoglossiforms (14.22%) and the Characiforms (13.31%). The other orders represent 1.74%. Families, the most in this fish assemblage are that of Cichlidae (41.79%), followed by that of Claroteidae (19.91%) and Alestidae (10.94%). The other families make up 27.36% of the fish caught. Seven (7) species dominate the lake population in terms of biomass: *S. melanotheron* (23.19%), *C. nigrodigitatus* (15.71%), *B. macrolepidotus* (7.2%), *H. niloticus* (6.63%), *C. anguillaris* (6.07%), *O. niloticus* (5.74%) and *T. zillii x T. guineensis* (5.49%). The others represent the remaining 29.97%. This order differs from that obtained for the numerical abundance of species. This difference implies that some species being well represented in numbers contribute little to the exploited biomass. Thus this low biomass of these species would be due to the presence of a large number of their juveniles in the catches. In addition, analysis of the seasonal variation of the lake population shows that the highest value of numerical abundance is obtained during the great rainy season (259.81 kg) and the lowest value during the short rainy season. (77.092 kg). In revenge, this variation of the biomass between the seasons shows a significant variation (p <0.05).

Size structure of the fish community

According to Sturge's rule, 14 size classes have been identified. The most represented class (modal class) is that of 4 to 10 cm followed by that of 10 to 16 cm and that of 16 to 22 cm. Moreover, the analysis of these size class differences shows that more than 81.64% of this population is smaller than 16 cm (Fig 3). The smallest size sampled is observed in cichlids with *T. zillii x T. guineensis* (4.3 cm). The largest size is noted in Arapaimidae with the species Heterotis niloticus (85 cm). In addition, these small individuals (size less than 16 cm) are harvested during all sampling with the highest proportion in August (93.79%). These results corroborate with the absence of some species that are well represented numerically are not preponderantly. Thus, this situation can be attributed to the use of multiple non-selective gear such as hawks, baited traps, seines and nets of small mesh on the lake. As a result, it will reduce the size of fish, their abundance, and even the survival of some species.

Table 3: Seasonal variation in the weight percentage of the main fish species sampled at the Ayamé 1 Dam from July 2017 to June 2018

Species	GDS	GRS	SDS	SRS
H. niloticus	2.27	12.35	4.28	0.11
B. macrolepidotus	8.72	6.91	6.21	4.3
C. nigrodigitatus	14.96	18.42	9.87	14.05
C. anguillaris	4.17	5.22	10.34	11.17
O. niloticus	2.47	8.27	8.98	2.06
S. melanotheron	34.79	17.07	14.88	19.14
T. zillii	5.04	4.54	6.74	2.69
T. zillii x T. guineensis	4.27	5.34	8.62	6.44
Total	76.69	78.12	69.92	59.96

GDS: great dry season, GRS: great rainy season, SDS: small dry season, SDS: small rainy season

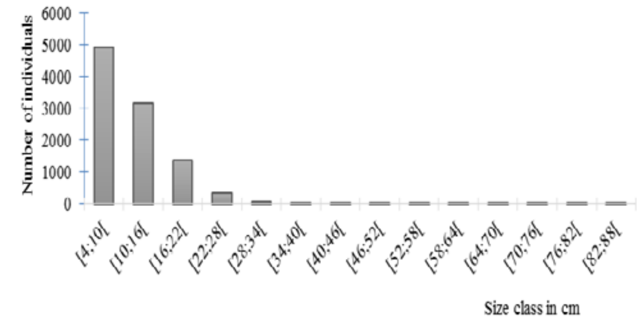

Fig 3: Structure of the size of fish collected at the dam lake Ayamé 1

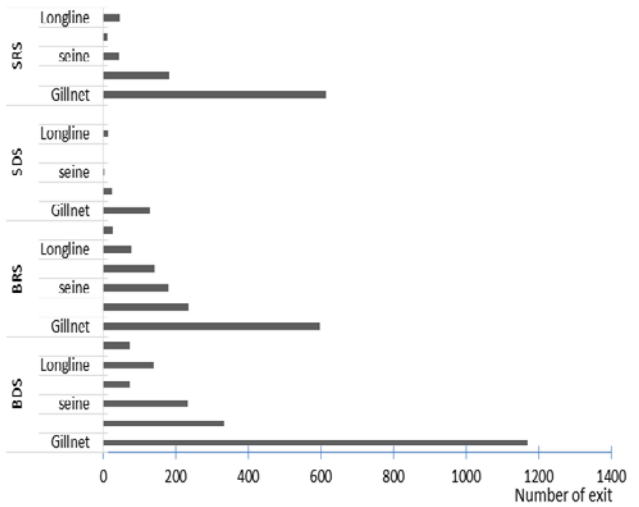

Fig 4: Seasonal variation in fishing effort by fishing gear in the Ayamé 1 Dam Lake from July 2017 to June 2018

Fishing effort and production

The fishing effort expressed is the number of fishing trips. On the lake as a whole, the fishing effort is 5779 trips and the total production expressed is 723488 kg. Gill nets (56.76% of trips) are the most used gear. They are followed by traps (18.29%) and seines (10.47%). Other gear such as hawk, trap-bamboo and longline contribute respectively to 5.34%, 1.89% and 7.25% in catches (Table 4). The seasonal variation in the use of the different gears shows that gill nets remain the most used in all seasons. They contribute to 1169; 825; 672 and 614 exits, respectively during the long dry season, the long rainy season, the short dry season and the short rainy season (Fig. 4).

Table 4: Fishing Effort by Gear at the Ayamé 1 Dam from July 2017 to June 2018

	Gillnet	Seine	Traps	Hawk	Longline	Bamboo-traps
Mean monthly effort	273 ± 90.41	47 ± 30.71	79 ± 35.36	26 ± 24.02	33 ± 21.63	9 ± 20
Total effort (output)	3280	605	1057	309	419	109
Total effort (%)	56.76	10.47	18.29	5.34	7.25	1.89

This same observation has been made in most lakes of hydroelectric reservoirs in Côte d'Ivoire (Kouassi, 1980; Traoré, 1996 (a supprimer); Da Costa and Dietoa, 2007). Indeed, on the lake of Ayamé dam this situation would be linked to the presence of many tree trunks on the water, which would reduce the impoundment of other gear (Tah, 2012). In addition, production is much higher than that of Tah (2012) estimated at 381.8 t after the departure of the fishermen "Bozo". This increase in production may be justified by the return of the latter to the fishery. Thus the production expressed reaches its maximum value (94530.9 kg) during the great dry season (Fig. 5). In fact, in general, production is high during the dry season and low during the rainy season (Bedia *et al.*, 2017). In our study, the production would therefore be related to the multiple fishing techniques used by these actors on the one hand and on the other hand a variation of fishing pressure (low during the rainy season and high during the dry season).

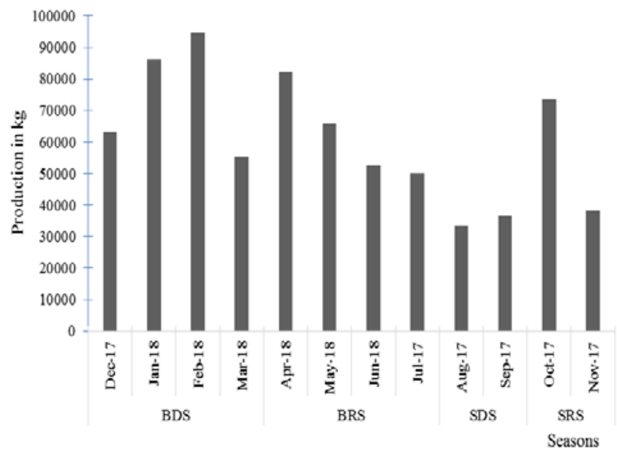

Fig 5: Seasonal variation in fish production at the Ayamé 1 Dam Lake from July 2017 to June 2018

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