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Zooplankton Productivity and Growth Performance of Three Fish Species (*Oreochromis niloticus, Heterotis niloticus* and *Hemichromis fasciatus*) in Polyculture Ponds in the Binomial Rainforest Zone of East Cameroon

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Abstract

One of the major constraints of production aquaculture is due to the partial control of the ecology of fish ponds. The study on the zooplankton productivity in polyculture of the three species of fish according to the type of pond was continued from January to December 2019 in the forest zone with binomial rainfall of East Cameroon in order to optimize production fish farming. For this purpose, 32 ponds including 16 bypass and 16 dam were used. The physicochemical characteristics of the water, zooplankton and fish growth were collected monthly according to standard methods. Transparency (42.64 ± 5.40 cm) and dissolved oxygen ((6.32 ± 1.71)*10^{-3} mg/dm^3)) values were significantly ($p < 0.05$) higher in bypass ponds. Conversely, nitrites ((0.04 ± 0.01)*10^{-3} mg/dm^3)) and ammonium ((0.30 ± 0.09)*10^{-3} mg/dm^3)) which were significantly ($p < 0.05$) higher in the ponds of dam. However, no significant difference ($p > 0.05$) was observed for temperature, pH, nitrates, ammonium and phosphates regardless of the type of pond. A total of 101 species, 33 genera and 20 family of the three groups of zooplankton have been identified in the bypass ponds. On the other hand, 83 species, 39 genera and 22 family have been identified in the dam ponds. The highest density values of rotifers (7 ± 5 ind/dm^3) and cladocerans (6 ± 4 ind/dm^3) were obtained in the dam ponds while that of copepods (6 ± 3 ind/dm^3) was observed in bypass ponds. The highest values of weight gain (390.28 ± 74.04g) and specific growth rate (0.76 ± 0.05%) in *O. niloticus* as well as those of weight gain recorded (2227.60 ± 392.35g) and the specific growth rate (0.93 ± 0.04%) recorded in *H. niloticus* were obtained in the dam ponds. At the end of the study, we recommend that fish farmers practice polyculture of the three species in the dam ponds.

Keywords: Productivity; Zooplankton; Growth; Polyculture; Pond

Introduction

Recent trends show a gradual increase in global aquaculture production following research into various production systems for the development of the sector [1]. In the rural world, most fish production is based on the exploitation of the natural productivity of earthen ponds in an extensive and / or semi-intensive system [2]. These fish ponds have ecological potentials responsible for the sustainable improvement of production fish farming systems, especially in developing countries. However, mastering the functioning of the ecosystem of fish ponds, an important lever for optimizing highly developed extensive and semi-intensive systems, requires knowledge of the natural production of the environment, in particular phytoplankton and zooplankton. The latter constitutes all the microorganisms of animal origin, suspended in the water column which feeds mainly on phytoplankton. It is an important element in the structuring and functioning of pond ecosystems. Thus, it is an essential food for fish due to its high protein content of around 54% [3], and excellent indicators of water quality in aquatic environments [4-6].

In Cameroon, work has been carried out on the productivity of zooplankton through fertilizers of animal origin (chicken droppings, pig manure, guinea pig droppings) in fish ponds [7-9]. Despite this work, little or almost nothing is known about how to effectively and optimally manage fish production in the different types of pond, especially bypass and dams. However, the development of an effective production management strategy would require a study of the ecological relationships of the pond in its diversity. This analysis would make it possible, through zooplankton species, to highlight the functional characteristics of the types of ponds studied as well as their yield in fish production. The objective of this study is therefore to assess the effect of pond type on the productivity of zooplankton groups as well as on fish production.

Material and Methods

Area and Period of Study

The study was carried out from January to December 2019 in diversion ponds and dams in the agro-ecological zone of the dense forest with bimodal rainfall in East Cameroon, Lom and Djerem departments, more precisely in the districts of Mandjou (13°62'5''N and 14°08'5''E), Bertoua 1st (04°34'30''N and 13°41'04''E) and Diang (04°35'00''N and 13°21'00''E). The average temperature fluctuates between 23 and 25 °C. The annual rainfall ranges from 1.500 - 1.800 mm, with two rainy seasons (mid-March to mid-June and mid-August to mid-November) and two dry seasons (mid-November to mid-March and mid-June to mid-August).

Animal Material

The fry used in this study are composed of three (03) species of fish namely: *Oreochromis niloticus* (nile tilapia) of average weight 22.68 ± 2.22 g and total length 11.12 ± 1.08 cm; by *Hemichromis fasciatus* (gendarme fish) of average weight 6 ± 1.2 g and total length 3.12 ± 0.08 cm; and juveniles *Heterotis niloticus* (kanga) of average weight 70 ± 1.12 g and total length 21.11 ± 1.08 cm were used in this study. These fry were the result of natural reproduction in fish production ponds. These different species were chosen so as to respect the farming model practiced by fish farmers in the study area.

Breeding Structure

In total, 32 fish production ponds including 16 bypass ponds with an average area of 975 m^2, an average depth of 0.70 m and 16 of a dam with an average area of 3600 m^2, an average depth of 1.24 m were used for rearing. To this end, the choice of production ponds were made respectively on the basis of areas with functional production ponds with high fish-breeding potential and on the stability of the fish farmer. The ponds chosen underwent a number of rearrangements before the start of the study, namely: the draining of the pond which consisted of the total emptying of the pond and the exposure of the mud from the plate in the sun for a week, filling and stocking the ponds.

Conduct of the Study and Data Collection

These ponds were stocked with male *Oreochromis niloticus* fry at a density of 0.5 tilapia/m^2, *Hemichromis fasciatus* at a density of 10% of the total density of *Oreochromis nilotucus* (i.e. 3660 fry of *Hemichromis fasciatus*) and used as predatory species to control sexing errors and juvenile *Heterotis niloticus* at a density of 0.8 ind/100m^2. At the start and end of the study, 30% of the total number of fish caught from each pond were weighed and measured using a 10 g precision balance and a centimeter ichthyometer, respectively. The physicochemical characteristics of the water were measured in situ and monthly between 6 and 10 hours following the methodology recommended by Rodier, et al. [10]. For this purpose, the transparency, the pH, the temperature and the dissolved oxygen were measured respectively with the help of a Secchi disc, a HANNA brand pH meter and a brand oxy-thermometer Handy Polaris. The determination of nitrites, nitrates, ammonium and phosphates were carried out using MACHEREY-NAGEL brand VISCOLOR ECO® test kits and the results are expressed in mg/dm^3.

Zooplankton Sampling

A volume of 20 liters of water per pond was collected by means of a zooplankton net of 50 µm mesh opening (shape: conical, depth: 40 cm and diameter: 20 cm) connected on a rod of length 1.20 cm. The zooplankton net was drained horizontally in the water for a distance of at least 20 m at a water depth of 30 cm from each type of pond. The process was repeated 3 times in each type of pond. After filtration, a sub-sample of $3x10^4$ cm^3 of zooplankton concentrate was retained, labeled, fixed with 5% formalin in the proportions of 25% formalin and 75% of the sample and stored in $5x10^4$ cm^3 plastic bottles for quantitative and qualitative laboratory analyzes [11].

In the laboratory, the identification and the enumeration of the different species of the zooplankton groups were made according to the methodology and the identification keys described by Legendre & Watt, Amoros, Durand and Levêque, Pourriot and Francez, Dussart and Defaye, Frontier and Zébazé [11-18]. After homogenization of the sample, $1x10^4$ cm^3 was taken using a calibrated pipette and placed in a 90 mm diameter Petri dish, gridded in 5 mm squares for inventory of zooplankton organisms. The identification and enumeration of the species of rotifers, cladocerans and copepods were carried out using a MOTIC brand binocular magnifier with 2X objective.

Characteristics Studied

Zooplankton characteristics

- **Density**

D = (n x 1000) / V where n = number of individuals found in the volume of water analyzed under the microscope, V = volume of water analyzed (in cm^3) and 1000 = conversion constant in liters

- **Relative abundance index (IAR)**

IAR = (NG / NT) × 100 where NG = Number of individuals of the given species and NT = Total number of individuals.

- **Shannon & Weaver diversity index (H ')**

H'= - Σ [(ni / N) × log2 (ni / N)] Where ni: number of species i in a sample, N: total number of individuals in the sample, s: number of species and log2: logarithm to base 2.

- **Pielou Equity Index (J)**

J = H '/ log2S where H' = Shannon and Weaver diversity index, log2 = logarithm to base 2 and S = number of species present

- **Simpson index (C)**

C = Σ Ni (Ni - 1) / N (N - 1) or Ni: number of individuals of the given species and N: total number of individuals

Growth characteristics of different species of fish:

- **Weight gain**

GP = Pmf - Pmi or Pmi = initial average weight (g) and Pmf = final average weight (g).

- **Specific growth rate**

TCS = [(LnPf -LnPi) / t] x 100 Where Pf = Average final weight of individuals during the test (g), Pi = Average initial weight of individuals during the trial (g), t = time or duration of the growth test period (day)

- **Condition factor K (load capacity of the medium)**

K = W * 100 / LT^3 with W = total weight (g), LT = total length (cm)

Statistical Analysis

The data collected was subjected to descriptive analysis. Student's test and Pearson's correlation were also used. Analyzes were performed using Statistical Package for Social Sciences (SPSS) Version 20.0 software.

Results

Physico-Chemical Characteristics of Water

The effect of pond types on the physicochemical characteristics of the water (Table 1) showed that the values of transparency and dissolved oxygen were significantly (p <0.05) higher in the bypass ponds. Conversely, nitrites and ammonium which were significantly (p <0.05) higher in the dam ponds. No significant difference (p>0.05) was recorded in the values of temperature, pH, nitrates and phosphates regardless of the type of pond. However, the values of temperature, nitrates and phosphates were higher in the dam ponds. The reverse was recorded for the pH value.

Physicochemical characteristics of water	Pond types		*P*
	Bypass (n=16)	Dam (n=16)	
Transparency (cm)	$42.64±5.40^a$	$32.65±6.20^b$	0
Temperature (°C)	$26.22±0.86^a$	$26.28±1.01^a$	0.65
pH (UI)	$6.96±0.27^a$	$6.90±0.30^a$	0.12
Disolved oxygen (mg/dm^3)	$(6.32±1.71)*10^{-3a}$	$(5.05±1.70)*10^{-3b}$	0
Nitrites (mg/dm^3)	$(0.03±0.01)*10^{-3b}$	$(0.04±0.01)*10^{-3a}$	0
Nitrates (mg/dm^3)	$(3.12±1.34)*10^{-3a}$	$(3.30±1.34)*10^{-3a}$	0.34
Ammonium (mg/dm^3)	$(0.28±0.09)*10^{-3b}$	$(0.30±0.09)*10^{-3a}$	0.04
Phosphates (mg/dm^3)	$(0.24±0.06)*10^{-3a}$	$(0.25±0.07)*10^{-3a}$	0.15

Table 1: Physico-chemical characteristics of the water according to the types of pond.
a, b: the means with the same letter on the same line do not differ significantly (p> 0.05), p = conversation, n = number of pond

Richness and Distribution of Family, Genera and Species of Zooplankton Groups According to The Types of Pond

The richness and distribution of family, genera and species of zooplankton groups (Tables 2 & 3) show that 120 species divided into 44 genera and 25 family belonging to the groups of rotifers, cladocerans and copepods were identified independently of the types of pond. The group of rotifers represented by 83 species, 24 genera and 18 family was the most diverse, followed by that of cladocerans represented by 29 species, 11 genera and 5 family. The less diverse group of copepods is made up of 8 species, 8 genera and one family. The highest values for species in the zooplankton groups (101 species) were recorded in bypass ponds and the lowest (83 species) in dam ponds. The families of Proalidae, Testudinellidae, Synchaetidae, Dicranophroridae have been identified only in dam ponds. In terms of genera, Lepadella, Colurella, Epiphaes, Rotaria and Acropenus were identified only in bypass ponds and those of Asplanchnella, Proalis, Testudinella, Polyathra, Lepadella, Encentrum, Rhynchotalona, Microcyclops, Bryocyclops, Macrocyclops and Tropocyclops in dam ponds.

Zooplanckon class		Pond types	
	Total	Bypass (n=16)	Dam (n=16)
Family	25	20 (80.00%)	22 (88.00%)
Genera	44	33 (75.00%)	39 (88.63%)
Species	120	101 (84.16%)	83 (69.16%)

Table 2: Influence of pond types on the richness of zooplankton taxa.
n = number of pond.

	Family	Genera	Nomber of species	
			Bypass (n=16)	Dam (n=16)
Rotifers	Brachionidae	*Brachionus*	16	8
		Platyias	2	2
		Keratella	3	2
		Lepadella	1	0
	Lecanidae	*Lecane*	16	9
	Synchaetidae	*Polyathra*	6	4
	Trochosphaeridae	*Filinia*	4	3
		Asplanchna	2	1
	Asplanchnidae	*Asplanchnella*	0	1
		Asplanchnipus	4	1
	Euchalanidae	*Euchlanis*	3	1
	Proalidae	*Proalis*	0	1
	Mytilinidae	*Mytilina*	2	3
	Testudinellidae	*Testudinella*	0	1
	Trichocercidae	*Trichocerca*	5	2
	Gastropodidae	*Ascomorpha*	2	2
	Synchaetidae	*Polyathra*	0	2
	Scaridiidae	*Scaridium*	2	4
	Lepadellidae	*Lepadella*	0	2
		Colurella	1	0
	Epiphanidae	*Epiphaes*	1	0
	Philodinidae	*Rotaria*	1	0
	Dicranophroridae	*Encentrum*	0	1

	Notommatidae	*Cephalodella*	1	1
	Daphniidae	*Ceriodaphnia*	6	5
		Simocephalus	1	1
	Chydoridae	*Chydorus*	4	2
		Acroperus	1	0
		Rhynchotalona	0	1
Cladocerans	Sididae	*Alonella*	2	2
		Alona	1	3
		Pleuroxus	1	3
		Diaphanosoma	2	1
	Moinidae	*Moina*	4	3
	Macrothricidae	*Macrothrix*	2	2
		Microcyclops	0	1
		Bryocyclops	0	1
		Ectocyclops	1	1
		Thermocyclops	1	1
Copepods	Cyclopidae	*Cryptocyclops*	1	1
		Mesocyclops	1	1
		Paracyclops	1	1
		Macrocyclops	0	1
		Tropocyclops	0	1
			101	83

Table 3: Influence of pond types on the distribution of zooplankton taxa.
n = number of pond

Characteristics of the Diversity and production of Zooplankton groups according to Pond types

The characteristics of the biodiversity and the production of zooplankton groups according to the types of pond are summarized in Table 4. It emerges that no significant difference ($p>0.05$) was obtained for values of the specific richness of zoplankton groups regardless of the type of pond.

Characteristics	Zooplankton groups	Ponds types		*P*
		Bypass (n=16)	Dam (n=16)	
Specific richness	Rotifers	31.00 ± 11.30^{a}	24.00 ± 5.80^{b}	0.04
	Cladocerans	9.00 ± 3.19^{a}	10.00 ± 3.10^{b}	0.52
	Copepods	4.00 ± 0.89^{a}	5.00 ± 1.88^{a}	0.14
Density (ind/dm^3)	Rotifers	$(5384\pm2114)*10^{-3a}$	$(6837\pm4307)*10^{-3a}$	0.31
	Cladocerans	$(871\pm527)*10^{-3b}$	$(5512\pm3568)*10^{-3a}$	0
	Copepods	$(5104\pm2839)*10^{-3a}$	$(4992\pm1643)*10^{-3a}$	0.46
Biomass (µg PS)	Rotifers	969.06 ± 380.58^{a}	1230.68 ± 775.35^{a}	0.31
	Cladocerans	1149.96 ± 695.53^{b}	7275.54 ± 4709.23^{a}	0
	Copepods	3593.55 ± 1788.59^{a}	3194.67 ± 1051.58^{a}	0.51
Simpson	Zooplankton species	0.71 ± 0.11^{a}	0.62 ± 0.10^{a}	0.12
Shannonn -Weaver		2.11 ± 0.44^{a}	1.64 ± 0.21^{b}	0.01
Equitability of Piélou		0.52 ± 0.10^{a}	0.42 ± 0.07^{b}	0.04

Table 4: Characteristics of the biodiversity and productivity of zooplankton groups according to the types of pond.
a, b: the means with the same letter on the same line do not differ significantly ($p> 0.05$), p = probability, n = number of pond

However, the highest value of rotifers was recorded in the bypass ponds. The reverse was observed for cladocerans and copepods with the highest values recorded in the dam ponds. On the other hand, the density and biomass values of cladocerans were significantly ($p<0.05$) higher in the dam ponds. However, no significant difference ($p>0.05$) was obtained for rotifers and copepods regardless of the type of pond. However, the highest density and biomass values of rotifers were obtained in dam ponds and those of copepods in bypass ponds. The Shannon-Weaver Diversity and Piélou Equitability Index values were significantly ($p<0.05$) higher in the bypass ponds. For the Simpson index, no significant difference ($p>0.05$) was observed. However, the highest value was obtained in the bypass ponds.

Production performance of three Species of Fish according to the types of Pond

The production performance of three fish species according to pond type is summarized in Table 5. It appears that the weight gain values of the three fish species were affected by the type of fish pond. In *O. niloticus*, no significant difference ($p>0.05$) was recorded regardless of the type of pond. However, the highest value was obtained in the dam ponds and the lowest in the bypass ponds. In *H. niloticus* and *H. fasciatus*, the values of weight gain were significantly ($p<0.05$) higher in the dam ponds and lower in the diversion ponds.

The value of specific growth rate were significantly ($p<0.05$) higher in dam ponds and lower in bypass ponds in *H. niloticus* and *H. fasciatus*. As for the value of the condition factor K, no significant difference ($p>0.05$) was recorded in *O. niloticus* and *H. niloticus*. However, the highest value was obtained in the bypass ponds and the lowest in the dam ponds. In *H. fasciatus*, the value of the condition factor K was significantly ($p<0.05$) higher in bypass ponds and lower in dam ponds.

The production yield values in *H. niloticus* and *H. fasciatus* were significantly ($p<0.05$) higher in the dam ponds and lower in the bypass ponds. However, no significant difference ($p>0.05$) was recorded in *O. niloticus* regardless of the type of pond. However, the highest value was obtained in the dam ponds and the lowest in the bypass ponds. As for the total production yield of three species of fish, no significant difference ($p>0.05$) was obtained regardless of the type of pond. However, the highest value was recorded in the dam ponds and the lowest in the bypass ponds.

Characteristics	Fish species	Ponds types		*P*
		Bypass (n=16)	Dam (n=16)	
Weight gain (g)	*Oreochromis niloticus*	343.76±56.56[a]	390.28±74.04[a]	*0.12*
	Heterotis niloticus	1766.03±299.83[b]	2227.60±392.35[a]	*0*
	Hemichromis fasciatus	31.23±5.80[b]	47.60±9.83[a]	*0*
Specific growth rate (%)	*Oreochromis niloticus*	0.74±0.05[a]	0.76±0.05[a]	*0.35*
	Heterotis niloticus	0.86±0.04[b]	0.93±0.04[a]	*0*
	Hemichromis fasciatus	0.40±0.05[b]	0.54±0.06[a]	*0*
Condition factor K	*Oreochromis niloticus*	3.31±0.17[a]	3.25±0.33[a]	*0.65*
	Heterotis niloticus	3.11±0.56[a]	3.07±0.39[a]	*0.88*
	Hemichromis fasciatus	3.26±0.26[a]	2.73±0.16[b]	*0*
Production yield (kg/ha/year)	*Oreochromis niloticus*	497.68±94.25[a]	535.82±1.02[a]	*0.4*
	Heterotis niloticus	2.45±0.66[b]	7.76±3.76[a]	*0*
	Hemichromis fasciatus	2.45±0.66[b]	7.76±3.76[a]	*0*
Total production yield (kg/ha/year)		661.46±135.18[a]	689.19±131.04[a]	*0.65*

Table 5: Production performance of three species of fish according to the type of pond.
a, b: the means with the same letter on the same line do not differ significantly ($p> 0.05$), p = probability, n = number of pond

Correlation between the Physicochemical characteristics and the Density of the Zooplankton Groups according to the types of Pond

The correlations between the physicochemical characteristics of the water and the density of the zooplankton groups according to the types of pond are summarized in Table 6. It appears that in the bypass ponds, the density of cladocerans was negative ($p<0.01$) correlated with nitrites, positive ($p<0.05$) correlated with ammonium. That of copepods was negative ($p<0.05$) correlated with nitrites. In dam ponds, the density of rotifers was positive ($p<0.01$) correlated with dissolved oxygen. That of copepods was negative ($p<0.05$) correlated with ammonium.

Ponds types	Groups of zooplankton	Transp	T	pH	O_2	NO_2^-	NO_3^-	NH_4^+	PO_4^{3-}
Bypass	Rotifers	0.05	-0.29	-0.39	-0.35	-0.16	0.14	0.39	0.37
	Cladocerans	-0.26	-0.37	0	0.22	-0.72**	0.05	+0.59*	0.42
	Copepods	-0.27	-0.11	0.04	-0.03	-0.67*	0.34	0.55	0.01
Dam	Rotifers	0.15	-0.06	-0.2	+0.72**	0.57	0.36	0.13	-0.56
	Cladocerans	0.02	0.03	-0.35	0.46	0.23	-0.12	-0.05	-0.45
	Copepods	0.08	-0.03	0.32	0.36	0.25	-0.05	-0.63*	-0.33

Table 6: Correlation between the physicochemical characteristics and the density of the zooplankton groups according to the types of pond

Trans: transparency, T: temperature, pH: potential of hydrogen, O_2: dissolved oxygen, NO_2^-: nitrite, NO_3^-: nitrate, NH_4^+: ammonium, PO_4^{3-}: total phosphate. *: significant correlation $p < 0.05$ (two-tailed), **: significant correlation $p < 0.01$ (two-tailed).

Correlation between the Growth Characteristics of the three Species of Fish and the Density of Zooplankton Groups according to the types of pond

The correlations between the growth characteristics of the three species of fish and the density of the zooplankton groups according to the types of pond are summarized in Table 7. It appears that in the bypass ponds, the densities of cladocerans and copepods were positive ($p<0.05$) correlated with condition factor K in *H. fasciatus*. In dam ponds, the density of rotifers was negative ($p<0.05$) correlated with the condition factor K in *H. niloticus*. That of cladocerans was negative ($p<0.05$) correlated with the specific growth rate in *H. fasciatus.*

Ponds types	Groups of zooplankton	*Oreochromis niloticus*			*Heterotis niloticus*			*Hemichromis fasciatus*		
		GP	TCS	K	GP	TCS	K	GP	TCS	K
Bypass	Rotifers	0.14	0.16	0.26	-0.1	0.08	-0.52	-0.28	-0.25	0.51
	Cladocerans	-0.37	-0.35	0.23	-0.34	-0.23	-0.38	-0.55	-0.52	+0.67*
	Copepods	-0.31	-0.31	0.05	-0.46	-0.38	-0.55	-0.54	-0.52	+0.59*
Dam	Rotifers	-0.13	-0.06	-0.4	-0.2	-0.26	-0.59*	-0.43	-0.55	0.35
	Cladocerans	-0.13	-0.06	-0.23	-0.34	-0.44	-0.09	-0.51	-0.59*	0.44
	Copepods	0.25	0.31	0.3	0.27	0.25	-0.25	0.14	0.02	0.31

Table 7: Correlation between the growth characteristics of the three species of fish and the density of the zooplankton groups according to the types of pond.

Gp: Weight gain (g), TCS: Specific growth rate (%), K: Condition factor, *: Significant correlation $p < 0{,}05$ (bilatéral).

Discussion

The results relating to the physico-chemical characteristics of the water showed that except for temperature, pH, nitrates and phosphates, the other characteristics were significantly affected by the type of pond. The values of the physico-chemical characteristics recorded remained within the favorable thermal interval recommended by Pourriot [15], Pouomogne [19], FAO and Malcolm, et al. [20] for better growth of zooplankton and the different fish species studied.

The concentrations of nitrites, nitrates, phosphates and pH were lower than those obtained by Nana [7] in ponds fertilized with chicken manure and pig manure in West Cameroon. Such a difference would be due to the presence of fish species in our ponds that feed on organic matter or phytoplankton in suspension, responsible for the increase in mineral elements after decomposition. The same observations were recorded by Kenfack, et al. [9] in ponds fertilized with pig manure and wheat bran in West Cameroon. The dissolved oxygen values were higher than those obtained by Nana [7] and Kenfack, et al. [9] in ponds fertilized with chicken manure and pig manure in West Cameroon. These results could be explained by the oxidation of organic matter carried out by biological or chemical means in the fertilized ponds [21]. The temperature values were higher than those reported by Nana and Kenfack, et al. [7,9]. This observation could be related to the ecological zone, since the water in the ponds of the Eastern region has a higher temperature than that of Western Cameroon.

Results values for zooplankton diversity and productivity characteristics were affected by the effect of pond type. The density of the three zooplankton groups was not significant ($p>0.05$) affected by the type of pond. The high density of zooplankton groups recorded in dam ponds compared to bypass ponds could be linked to the management of the natural productivity of the environment. The continuous supply of water to the dam ponds is believed to be the main cause of the increase in zooplankton density, as the organic matter responsible for the production of zooplankton is continuously carried by the current of water into the pond. The highest values of zooplankton group biomass recorded in dam ponds compared to bypass ponds are due to the high density of different zooplankton groups. The value of rotifer species richness was higher in bypass ponds compared to dam ponds. These results would be related to the trophic state and the physicochemical characteristics of the water. The values of the Simpson diversity Index, Shannon-Weaver and Piélou Equitability were higher in bypass ponds compared to dam ponds. This could be justified by the fact that the dam ponds present favorable conditions for the establishment and maintenance of a balanced community [22].

The production performance results of three species of fish were affected by the effect of pond type. The values of weight gain, specific growth rate, total length gain and production yield recorded in *O. niloticus*, *H. niloticus* and *H. fasciatus* were higher in dam ponds compared to bypass ponds. These results could be justified on the one hand by the high densities of rotifers and cladocerans, on the other hand by the contribution of insects, insects and macro invertebrates from runoff during the rainy season. Similar observations were obtained from Adite, et al. Kouakou, et al. Odo, et al. [23-25] which stipulate that the richness of the environment in ammonium ions, phosphates and nitrites resulting from the decomposition of organic matter would promote in addition to zooplankton the development of benthic invertebrates and these micro-crustaceans responsible for the good growth of species of fish. The K condition factor values were greater than 3 regardless of the pond type. These results corroborate with Fulton's [26] assertion that fish are healthy in their culture environment when $K>1$. Indeed, Koman, et al. [27] have shown that the high values of the condition factor K may be due to the presence of a diversified and abundant diet in the breeding environment.

Conclusion

The physicochemical characteristics of the water showed that except for temperature, pH and nitrates all other characteristics were significantly affected by the effect of pond type during the study. However, the values of the physico-chemical characteristics recorded remained within the favorable thermal interval recommended for better production of zooplankton and of the different fish species studied. Regarding the characteristics of zooplankton diversity, the specific richness of rotifers is higher in bypass ponds, those of cladocerans and copepods in dam ponds. The rotifers species are more abundant compared to the species of cladocerans and copepods regardless of the type of ponds. On the other hand, the density and biomass of rotifers and cladocerans are higher in the dam ponds. The reverse is observed for the values of copepods. The growth characteristics of fish species are affected by the type of pond. Values for weight gain, specific growth rate and production yield obtained in *O. niloticus*, *H. niloticus* and *H. fascicatus* are higher in dam ponds. In view of the results, we recommend that fish farmers to practice polyculture of the three species were higher in the dam ponds.

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