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Diversity and seasonal pattern of Chironomidae (Insecta; Diptera) in seven lotic systems of Southeast Côte d'Ivoire (West Africa)

Dramane Diomande*, Idrissa Adama Camara, Edia Oi Edia, Germain Gourene

Laboratoire d'Environnement et de Biologie Aquatique, Université Nangui Abrogoua, 02 BP 801 Abidjan 02, Côte d'Ivoire

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Abstract

This study aimed to evaluate the spatial and seasonal variation of the richness and abundance of Chironomidae larvae and related its distribution to physical and chemical variables in seven lotic systems of Southeast Côte d'Ivoire. Two sampling stations were retained in each system. Chironomidae were sampled at two occasions during each season using a triangular hand net (10 X 10 X 10 cm, 250 µm mesh, 50 cm length). Thirteen genera were identified in three subfamilies (Chironominae, Tanypodinae and Orthocladiinae). Chironominae, with 67.75% of the relative abundance, was the most diversified subfamily, followed by Tanypodinae (23.27%) and Orthocladiinae (9.23%). Agnéby River contained the most diversified community with eleven genera, whereas the least diversified was encountered in Bia River (7 genera). *Polypedilum* and *Tanytarsus* were the dominant taxa in the study area. Genus richness was in general higher in rainy season in rivers Agnéby and Bia, while it was higher in dry season in the others streams. The correspondence analysis revealed that substrate characteristics, current flow, and water mineralization level were the major factors acting upon the chironomid communities. Chironomidae can be used as a potential instrument in future ecology studies in lotic systems of Southeast Côte d'Ivoire.

***Corresponding Author:** Dramane Diomande ✉ diom_dram@yahoo.fr

Introduction

Chironomidae is a family of aquatic flies (Diptera) with worldwide distribution (Leonard and Ferrington, 2008). The larvae of this family contribute to nutrient cycling in aquatic environments by accelerating decomposition through vegetable materiel fragmentation from the riparian forest (Sanseverino and Nessimian, 2008), and constitute food resource for amphibians (Dutra and Callisto, 2005), reptiles (Novelli *et al.,* 2008), invertebrates (Walker, 1987).

In regard to the economic importance, chironomids larvae are utilized as fish food resource (Rezende and Mazzoni, 2003). Some species are plagues in rice fields, feeding on recently germinated seeds, seedlings, stem and leaves, causing damages to the agriculture (Al-Shami *et al.,* 2008). There are reports and studies about allergic diseases induced by mass emergencies of Chironomidae adults (Cranston, 1995).

The chironomidae exhibit a great ecological diversity, living under a wide range of environmental conditions, with species that tolerate low concentration of oxygen and extremes of temperature, pH, salinity and nutrients (Leonard and Ferrington, 2008). Therefore, they are often included in most ecological and toxicological studies (Fonseca-Leal *et al.,* 2004).

Despite their obviously important function in aquatic ecosystems and their role as a substantial food source for numerous entomophagous fishes, the African chironomids remain a little studied (Hilde and Henri, 2005). In West Africa, more precisely in Côte d'Ivoire, several studies have been conducted with aquatic insects (eg. Diomandé *et al.,* 2010; Kouadio *et al.,* 2011; Camara *et al.,* 2012), although little is known about the chironomid communities in this country (Diomandé *et al.,* 2000). However, high richness of Chironomidae is expected in this region located in the equatorial rain forest. Therefore, our objective was to contribute to the knowledge of Chironomidae in this region by making the survey of Chironomidae composition in seven lotics systems in Southeast Côte d'Ivoire, and relate its distribution to physical and chemical variables.

Materials and Methods

Study area

The study was carried out in seven coastal lotic systems (Agnéby River, Bia River, Banco Stream, Ehania Stream, Eholié Stream, Noé Stream, Soumié) located in the Southeast of Côte d'Ivoire (Fig. 1). The climate in these studies areas is typical of the equatorial rain forest, comprising four seasons (Girard *et al.,* 1971): a Great Dry Season (GDS) from December to March, a Great Rainy Season (GRS) from April to July, a Small Dry Season (SDS) from August to September, and a Small Rainy Season (SRS) from October to November. Air temperature in the Southeast Côte d'Ivoire average 27°C, and the annual precipitation of approximately 1600 – 2500 mm (Kouamé *et al.,* 2008).

Agnéby River (5° - 7° N and 4° - 5° W) is 200 km in length, with a mean annual flow of 22 m^3. sec^{-1}. It flows into the Ebrié Lagoon and covers a catchment area of 8600 km^2. The main riparian vegetation consists of industrial farms. This river is characterised by its substratum heterogeneity (mud, sand, gravel, and woody debris), with aquatic vegetation in the downstream areas.

Banco Stream (5°25' N and 4°01'W) is a short river with 9 km in length. It is located in the Banco National Park in the centre of Abidjan (economic capital). It has a catchment area of 30 km^2, flows into the Ebrié Lagoon, and has an annual mean flow of 1.35 m^3. sec^{-1}. The upstream and downstream areas of this river are characterized by substratum heterogeneity (mud, sand, and woody debris), and are not affect by human disturbance. Meanwhile, the midstream areas receive municipal untreated waste waters and surface run-off from Abobo city. This area is also subject to organic pollution arising from effluents from a civilian prison. The substratum in the midstream area is mainly sandy, with a lack of aquatic vegetation. Water is sometime eutrophic in this area, with substantial algal growth (Camara *et al.,* 2009). The mean depth in Banco Stream varied from 0.02 to 0.7 m, and the mean width ranged from 1.21 to 8.9 m.

Bia River (5°5' N and 2°6' W) comes from Ghana and flows into the Aby Lagoon in Southeast Côte d'Ivoire. It has a total length of 300 km with 120 km in Côte d'Ivoire. It covers a catchment area of 9 300 km^2, and has a mean width of 150 m. A man-made lake (Lake Ayamé) has been created on Bia River channel in Côte d'Ivoire since 1959 for electrical purpose (Diomandé, 2001). Lake Yamé (5°37' N and 3°10' W) is fed by many rivers, with a surface of 180 km^2, a volume of at least 1000 000 000 m^3, and a mean depth of 12 m. The substratum along Bia River is composed by mud, and sand, with its downstream areas affected by Lake Ayamé regulation.

Soumié Stream (5°29' N and 3°17' W) is a tributary of the Bia River. Its drainage area covers 395 km^2. It is 41 km in length with a mean annual flow of 11.76 $m^3.sec^{-1}$. Its mean depth varied from 0.84 to 1.41 m, and a mean width ranged from 14.34 to 16.92 m. Industrial farms constitute the main adjacent land use. The predominant substratum in the upstream areas are mainly gravel, and sand, while in the downstream areas, the substratum are mainly composed of woody debris and mud.

Eholié Stream (5°28' N and 3°08' W) is 35 km in length, with a mean depth varied between 1.27 m and 1.88 m. Its mean width varied from 22.18 to 22.28 m. It covers a catchment area of 373 km^2 and flows into the Aby Lagoon, with an annual flow of 11.4 $m^3.sec^{-1}$. The predominant substratums in the upstream areas are mainly sand and mud, while the substratum in the downstream is sandy. Forest is the main riparian vegetation along this river.

Noé Stream (5°28' N and 2°46' W) and Ehania Stream (5°24' N and 2°50' W) are both tributaries of Tanoé River. Their catchments areas cover 238 and 585 km^2 respectively. With a length of 30 km, Noé Stream has a mean annual flow of 9.56 $m^3.sec^{-1}$. Its mean depth varied from 0.69 to 2.28 m, and the mean width varied from 11.11 to 15 m. Housing cultivated are the main adjacent land use. The substratum in the upstream areas is mainly sand and mud, with gravel substratum in the downstream areas. EhaniaStream has an annual mean flow of 15.74 $m^3.sec^{-1}$. Its mean width varied from 15.58 to 29.93 m, and the mean depth varied from 1.44 to 2.29 m. Sand and mud are the main substratum found in the upstream areas, while woody debris is the main substrate in the downstream areas, with housing cultivated as adjacent land use.

Sampling design

In each of these coastal lotic systems, two sampling stations were retained: one in the upstream and the other one in the downstream. Except for the Banco, where one station has been added in the disturbed midstream areas. The location of each sampling station is shown in figure 1.

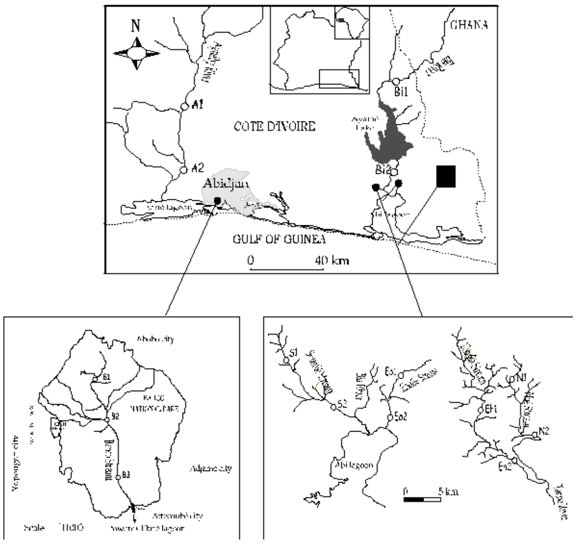

Fig. 1. Location of the study areas showing the seven lotic systems (Agnéby River. Bia River. Banco Stream. Ehania Stream. Eholié Stream. Noé Stream. and Soumié Stream) in Southeast Côte d'Ivoire with the sampling stations (Agnéby: A1. A2; Banco: B1. B2. B3; Bia: Bi1. Bi2; Ehania: Eh1. Eh2; Eholié: Eo1. Eo2; Noé: N1. N2; Soumié: S1. S2).

Chironomid samples from Agnéby and Bia rivers were given by Diomandé (2001). Samples of Banco Stream were given by Camara (2013), and those from Ehania, Eholié, Noé and Soumié streams were given by Edia (2008). The Chironomidae larvae were sampled at each station on eight occasions (i.e four during the rainy seasons and four in the dry seasons). They were sampled using a triangular hand net (10 X 10 X 10 cm, 250µm mesh, 50 cm length). For each sample, the net was dragged over the river bed for a distance of 10 m, maintaining contact with the substrate. In each sampling occasion, two replicate samples were collected at each station, considering all possible microhabitats over representative section of the river. The samples were sieved in the field through a 1 mm mesh, and the material retained on the mesh was transferred to buckets with watertight lids and preserved with 5% formaldehyde.

In the laboratory, the chironomid larvae were hand sorted in large white tray, then counted and identified to the generic level except for the samples from Banco Stream where chironomid larvae were identified to the subfamily level. The larvae were macerated in a hot 10% lactophenol solution and identified under a microscope (400X) with the aid of taxonomic keys (Diomandé *et al.,* 2000; Elper, 2001; Michael and Bolton, 2007).

Five environmental variables were used to describe physicochemical water condition at each sampling station. We measured electrical conductivity and total dissolved solids (TDS) (with WTW-LF 340), pH (with a pH-meter WTW-pH 330), water temperature (using a thermometer built into the pH-meter), and dissolved oxygen (with an oxymeter WTW-DIGI 330). All these variables were measured in the field before biological sampling. The habitat variables of the studied rivers such as water depth, width, current flow and substrate type were characterized in previously studies (Edia *et al.,* 2007; Camara *et al.,* 2009, Diomandé *et al.,* 2009).

Data analysis

Chironomid structure was described through taxonomic composition and relative abundance.

Before performing the comparison test, the normality of data was checked by the Kolmogorov-Smirnov test (p >0.05 at all stations). So, the Kruskal-Wallis test, a non-parametric test, was performed to compare environmental variables between sampling stations using the STATISTICA 7.1. A significance level of p <0.05 was considered.

In order to study relationships between environmental variables and the distribution of the Chironomidae subfamilies, Canonical Correspondence Analysis (CCA) was performed based on the data matrix of subfamilies abundance. Environmental variables and chironomid data were log10(x + 1) transformed prior to analysis. Monte Carlo permutations (500) were done in order to identify a subset of measured environmental variables, which exerted significant and independent influences on chironomid distribution at p <0.05. CCA was performed using CANOCO 4.5 (Ter Braak and Smilauer, 2002). In addition, correlations between environmental variables and chironomid genera were tested by the Spearman correlation test.

Results

Environmental variables

Table 1 shows the summary of the environmental variables of the seven study lotic systems of Southeast Côte d'Ivoire. As regard water pH, the studied stretches presented acid to slightly neutral waters, with pH varying between 4.11 (B3: Banco Stream) and 7.56 (Bi1: Bia River). pH values were significantly higher in Bia River stations than those registered in Banco Stream stations (Kruskal-wallis test, p ≤ 0.05). Water temperature varied between 22.10 °C (A1: Agnéby River) and 28.02 °C (B1: Banco Stream). It was relatively uniform among the study area with slight spatial variation (Kruskal-wallis test, p > 0.05). Concerning water electrical conductivity, the highest values were observed in both Agnéby River (118.88 – 149.15 µS/cm) and Bia River (92.95 – 121.18 µS/cm). While the lowest values were observed into the streams (at least < 94.17 µS/cm). Conductivity was significantly higher at station A1, A2 and Bi1 than those reported at stations B1 and B 3 (Kruskal-wallis test, p ≤ 0.05). High Total Dissolved Solids (TDS) were found in Bia River at station Bi1 (60.30 mg/L), and in Agnéby River at stations A1 (73.9 mg/L), and A2 (68.20 mg/L). It was lower into the other stations and varied from 16 mg/L (B1: Banco Stream) to 46.33 mg/L (Bi2: Bia River). TDS was significantly different between Agnéby River stations and those reported at station B1 (Banco Stream) and station S2 (Soumié Stream) (Kruskal-wallis test, p ≤ 0.05). Dissolved oxygen varied from 3.05 mg/L (B2: Banco Stream) to 9.82 mg/L (Eh2: Ehania Stream; N2: Noé Stream). Dissolved oxygen were significantly lower at station B1 (Banco Stream) than those registered in Ehania Stream (Eh2) and Noé Stream (Kruskal-wallis test, p ≤ 0.05).

Table 1. Environmental variables evaluated in seven coastal lotic systems (Agnéby: A1, A2; Bia: Bi1, Bi2; Ehania: Eh1, Eh2; Eholié: Eo1, Eo2; Noé: N1, N2; Soumié: S1, S2) in Southeast Côte d'Ivoire, and results of the Kruskal-Wallis test. Med: median, Min: minimum, Max: maximum. Medians in the same line followed by different letters are significantly different (p ≤ 0.05).

Environmental parameters		Agnéby		Banco			Bia		Ehania		Eholié		Noé		Soumié	
		A1	A2	B1	B2	B3	Bi1	Bi2	Eh1	Eh2	Eo1	Eo2	N1	N2	S1	S2
Water Temperature (°C)	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Med	24.31a	26.43a	25.94a	26.49a	26.34a	25.64a	26.86a	25.54a	26.00a	25.86a	26.03a	25.50a	26.15a	25.25a	25.68a
	Min	22.10	25.73	25.28	25.57	25.88	25.05	25.60	24.60	25.15	25.00	25.05	24.95	25.10	24.40	24.43
	Max	25.28	26.78	27.03	28.02	27.68	26.05	27.33	26.20	26.95	26.75	27.10	26.10	27.60	26.40	27.40
Conductivity (µS/cm)	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Med	141.12a	133.10a	23.20b	75.10ab	33.80b	115.92b	82.82ab	63.63ab	54.03ab	54.93ab	56.80ab	64.35ab	53.83ab	57.09ab	42.92b
	min	118.88	124.25	21.69	47.24	21.78	109.93	63.55	60.40	49.60	52.30	54.15	60.90	52.95	53.20	39.10
	max	149.15	142.78	26.00	94.17	47.12	121.18	92.95	67.80	58.50	57.40	59.95	68.00	54.60	60.80	45.35
Total dissolved solids (mg/L)	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Med	69.62a	60.42a	18.37b	40.57ab	28.65ab	57.84ab	41.17ab	29.45ab	25.33ab	25.66ab	26.66ab	30.12ab	25.08ab	27.16ab	20.16b
	min	65.90	54.30	16.00	29.50	22.25	54.83	31.65	28.00	23.00	24.50	25.50	28.50	24.50	25.00	19.00
	max	73.90	68.20	21.75	58.17	35.00	60.30	46.33	31.50	27.50	26.67	28.50	32.00	25.50	29.00	21.00
Dissolved oxygen (mg/L)	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Med	5.98ac	4.46ac	4.80ac	3.69a	4.49ac	6.36ac	6.86ac	5.08ac	7.77bc	5.88ac	7.34ac	7.23bc	7.65bc	4.36ac	5.34ac
	min	5.60	3.80	4.07	3.05	4.11	5.77	5.45	4.04	6.52	5.04	5.45	6.28	6.67	3.55	4.50
	max	6.50	5.05	6.03	4.30	5.34	7.65	7.75	6.09	9.82	6.42	8.71	7.85	9.82	5.27	5.99
pH	N	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	Med	7.11ab	7.13ab	5.14b	5.74b	4.97b	7.46a	7.29a	7.08ab	6.85ab	6.95ab	6.97ab	6.95ab	6.54ab	7.06ab	6.83ab
	min	6.81	7.08	4.68	5.17	4.49	7.37	7.14	6.92	6.74	6.87	6.89	6.58	5.76	6.76	6.58
	max	7.59	7.18	5.42	6.52	5.70	7.56	7.42	7.16	7.05	7.06	7.11	7.13	6.92	7.48	7.04

Composition and spatial distribution

Chironomidae communities include 13 genera and 3 subfamilies (Chironominae, Tanypodinae and Orthocladiinae) (Fig. 2). The fauna is dominated by the Chironominae with 7 genera (*Chironomus*, *Cryptochironomus*, *Nilodorum*, *Polypedilum*, *Stenochironomus*, *Stictochironomus*, *Tanytarsus*), followed by Tanypodinae with 4 genera (*Ablabesmyia*, *Clinotanypus*, *Procladius*, *Tanypus*). Orthocladiinae contained 2 genera (*Cricotopus*, *Nanocladius*).

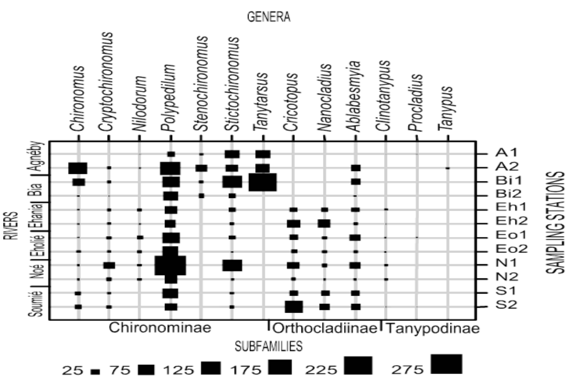

Fig. 2. Abundance of the recorded Chironomidea genera in six coastal lotic systems (Agnéby. Bia. Ehania. Eholié. Noé. Soumié) of Southeast Côte d'Ivoire.

Analysis of samples from the seven study lotic systems yielded 4723 Chironomidae larvae of which subfamily Chironominae was the most abundant with 67.75% of the relative abundance. The relative abundance of Tanypodinae and Orthocladiinae were respectively 23.27% and 9.23%.

Subfamilies Chironominae and Tanypodinae were sampled in all the rivers studied while Orthocladiinae was missed in rivers Agnéby and Bia. Eleven of the thirteen genera sampled were recorded in Agnéby River. Ten genera were recorded in Eholié Stream. Nine genera were recorded both in Ehania Stream and Noé Stream. Soumié and Bia streams recorded respectively 8 and 7 genera of Chironomidae.

From the three subfamilies of Chironomidae sampled in the study area, Chironominae was the dominant group at the different stations except station Eh2 and station S2 where Orthocladiinae was most abundant. Regarding genera, *Tanytarsus* and *Stictochironomus* (Chironominae) were the dominant taxa at station A1 and Bi1. *Nanocladius* and *Cricotopus* (Orthocladiinae) were the most abundant taxa at station Eh2, while *Polypedilum* (Chironominae) was the predominant taxon at the other stations. *Cricotopus* were the most abundant taxa at station S2 (Fig. 2). Samples collected from Banco Stream were not taken into account in this analysis because the identification of the chironomid larvae from this stream was limited to the subfamily level.

Seasonal pattern of chironomid genera

Samples collected from Banco Stream were not taken into account in this analysis because the identification of the chironomid larvae from this stream was limited to the subfamily level.

In Agnéby River, Chironomidae seasonal richness varied from 2 (GDS) to 5 (GRS) at station A1, and 3 (SDS) to 9 (GRS) at station A2 (Fig. 3). *Stictochironomus* was dominant in all the seasons at station A1 except SDS where *Tanytarsus* was most abundant. *Stenochironomus*, *Chironomus*, *Stictochironomus* and *Polypedilum* were the most abundant taxa respectively in GDS, GRS, SDS, and SRS at station A2. Concerning Bia River, the richness varied between 1 (SRS) and 8 (GRS) at station Bi1, and between2 (GDS) and 5 (GRS) at station Bi2. *Polypedilum* was the most abundant taxon in all the seasons at station Bi2, and in GRS atstation Bi1. *Tanytasrsus* dominated both in GDS and in SDS, while *Stictochironomus* was most abundant in SRS at station Bi1. As regard Ehania Stream, the richness varied from 6 (GDS; GRS) to 8 (SDS) at station Eh1. It varied from 3 (GRS) to 6 (GDS; SDS) at station Eh2. *Polypedilum* was the most abundant taxon in all the seasons at station Eh1. At station Eh2, *Cricotopus* was the most abundant taxon both in GDS and in GRS. *Nanocladius* and *Polypedilum* were the most abundant taxa respectively in SDS and in SRS at this station.

In Eholié Stream, Chironomidae seasonal richness varied from 4 (GRS) to 7 (GDS; SRS) at station Eo1 and 4 (GDS; SRS) to 7 (SDS) at station Eo2. *Polypedilum* was the most abundant taxon in all the seasons at each station in this river (Fig. 4). It was the same for Noé Stream where the richness varied from 4 (SRS) to 9 (GDS) at station N1 and 2 (GDS) to 7 (SDS) at station N2. Concerning Soumié Stream, the richness varied between 4 (GDS; SRS) and 6 (SDS) at station S1, and between 3 (SRS) and 8 (SDS) at station S2. *Polypedilum* was the most abundant taxon in all the seasons at station S1. At station S2, *Cricotopus* was the most abundant taxon in SRD and in SDS, while *Polypedilum* dominated both in GDS and GRS.

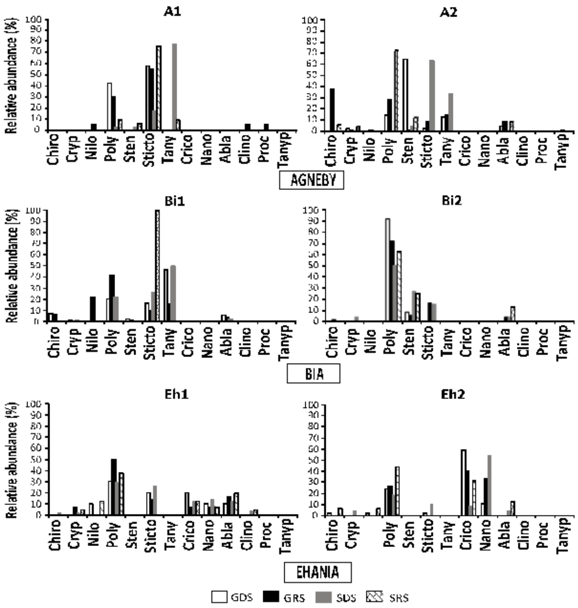

Fig. 3. Seasonal relative abundance of Chironomidae genera found in Agnéby River. Bia River and Ehania Stream in Southeast Côte d'Ivoire; Stations (A1. A2. Bi1. Bi2.Eh1. Eh2); with the Chironomidae genera (Chir = Chironomus. Cryp = Cryptochironomus. Nilo = Nilodorum. Poly = Polypedilum. Sten = Stenochironomus. Sticto = Stictochironomus. Tany = Tanytarsus. Crico = Cricotopus. Nano = Nanocladius. Abla = Ablabesmyia. Clino = Clinotanypus. Proc = Procladius.Tanyp = Tanypus); GDS = great dry season; GRS = great rainy season; SDS = small dry season; SRS = small rainy season.

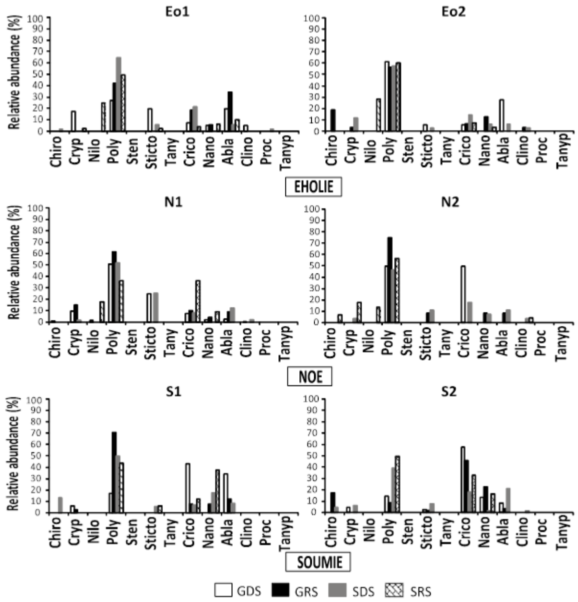

Fig. 4. Seasonal relative abundance of Chironomidae genera found in Eholié Stream Noé Stream and Soumié Stream in Southeast Côte d'Ivoire; Stations (Eo1. Eo2. N1. N2.S1. S2); with the Chironomidae genera (Chir = Chironomus. Cryp = Cryptochironomus. Nilo = Nilodorum. Poly = Polypedilum. Sten = Stenochironomus. Sticto = Stictochironomus. Tany = Tanytarsus. Crico = Cricotopus. Nano = Nanocladius. Abla = Ablabesmyia. Clino = Clinotanypus. Proc = Procladius. Tanyp = Tanypus). GDS = great dry season; GRS = great rainy season; SDS = small dry season; SRS = small rainy season.

Relationships between environmental variables and chironomid taxa

The results of the correspondence analysis revealed that the relationships between the three Chironomidae subfamilies and their habitat conditions follow mainly the first two axes (Fig. 5). These two axes accounted for 93.9% of the total variance and evidenced a spatial pattern in the chironomid assemblage of the study area.

The first axis (Axe1) opposed samples of Banco, Agnéby and Bia in positive coordinates to those of Soumié, Noé, Ehania, and Eholié in negative coordinates. Orthocladiinae and the other two subfamilies (Chironominae and Tanypodinae) were also opposed according to the same interpretations. This axis showed a mineralization gradient. High of Orthocladiinae and Tanypodinae abundance were negatively influenced by high values of conductivity, total dissolved solids and pH. The second axis (Axe2) mainly opposed the samples of Banco Stream in positive coordinates to the samples from rivers Agnéby, and Bia in negative coordinates. According this axis, abundance of subfamilies Orthocladiinae and Tanypodinae were negatively influenced by high percentage of sand and mud in the substratum.

Meanwhile, subfamily Chironominae, which was placed in the central part of the graph, seemed to be adapted to all the environmental variables used in this study.

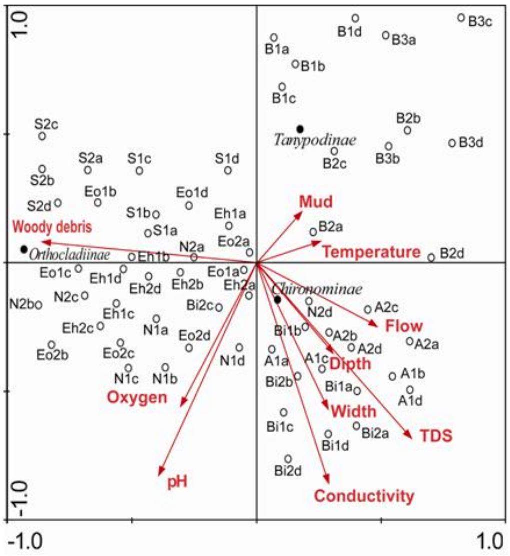

Fig. 5. Canonical correspondence analysis triplot showing Chironomidae subfamilies and sampling stations in relation to environmental variables in seven coastal lotic systems (Agnéby: A1. A2; Bia: Bi1. Bi2; Ehania: Eh1. Eh2; Eholié: Eo1. Eo2; Noé: N1. N2; Soumié: S1. S2) of Southeast Côte d'Ivoire. a = great dry season; b = great rainy season; c = small dry season; d = small rainy season.

The Speaman's correlation analysis revealed that *Nilodorum* and *Stenochironomus* abundance were significantly and positively correlated with water temperature, while *Stictochironomus* was significantly and negatively correlated with this variable. Conductivity, total dissolved solids (TDS), and water pH had significant and positive correlation with *Stenochironomus*, *Stictochironomus*, and *Tanytarsus*. These parameters were significantly and negatively correlated with *Cricotopus* and *Nanocladius*. *Ablabesmia* abundance was negatively correlated with dissolved oxygen (Table 2).

Table 2. Spearman correlation of Chironomidea genera abundances and environmental variables of Southeast Côte d'Ivoire lotic systems.

		Environmental variables									
		Temperature		Conductivity		TDS		Oxygen		pH	
Genus	**n**	**r**	**p**	**r**	**p**	**r**	**p**	**r**	**p**	**r**	**p**
Chironomus	8	0,11	ns	0.03	ns	-0.01	ns	-0.01	ns	0.12	ns
Cryptochironomus	8	-0.08	ns	-0.04	ns	-0.07	ns	-0.08	ns	0.09	ns
Nilodorum	8	0.37	*	0.02	ns	-0.02	ns	0.07	ns	-0.15	ns
Polypedilum	8	-0.13	ns	0.04	ns	0.01	ns	-0.01	ns	0.24	ns
Stenochironomus	8	0.29	*	0.61	**	0.62	**	-0.17	ns	0.58	*
Stictochironomus	8	-0.29	*	0.46	*	0.46	*	-0.19	ns	0.32	*
Tanytarsus	8	-0.04	ns	0.55	*	0.55	*	-0.26	ns	0.43	*
Cricotopus	8	-0.24	ns	-0.65	**	-0.66	**	0.06	ns	-0.48	*
Nanocladius	8	-0.28	ns	-0.48	*	-0.49	*	-0.04	ns	-0.30	*
Ablabesmyia	8	-0.16	ns	-0.11	ns	-0.14	ns	-0.32	*	0.14	ns
Clinotanypus	8	-0.08	ns	-0.12	ns	-0.14	ns	0.20	ns	-0.20	ns
Procladius	8	-0.11	ns	0.13	ns	0.12	ns	-0.08	ns	-0.10	ns
Tanypus	8	0.14	ns	0.19	ns	0.13	ns	-0.22	ns	0.05	ns

r = Spearman correlation coefficient; * or ** = indicates significant difference (p ≤ 0.05 or 0.01); ns = non-significant relationship.

Discussion

Three subfamilies (Chironominae, Orthocladiinae, Tanypodinae), and 13 genera were identified from family Chironomidea in this study. These subfamilies are the most commonly found in West Africa aquatic habitats (Diomandé *et al.,* 2000; Hilde and Henri, 2005), and are known to have worldwide distribution (Leal *et al*., 2004; Rosin *et al.,* 2009).

Chironominae with 7 genera (*Chironomus*, *Cryptochironomus*, *Nilodorum*, *Polypedilum*, *Stenochironomus*, *Stictochironomus*, *Tanytarsus*) was the most diverse and abundant (67.75%) subfamily of Chironomidae in this study, corroborating the results of studies from Brazilian aquatic habitats (Rosin and Takeda, 2007; Vieira *et al*., 2012). Tanypodinae with 4 genera (*Ablabesmyia*, *Clinotanypus*, *Procladius*, *Tanypus*) was the medium diverse and abundant (23.27%) subfamily. Orthocladiinae, with 2 genera (*Cricotopus*, *Nanocladius*), is the least diverse and abundant (9.23%) group. All these Chironomidae genera were already reported in West Africa aquatic habitats (Hilde and Henri, 2004).

Orthocladiinae was missed in Agnéby and Bia rivers but was found in all the streams with low abundance. Unfavorable environmental condition could probably be the reason (Ebrahimnezhad and Fakhri, 2005).

With 11 of the 13 genera recorded, Agnéby River was the most diverse in term of generic richness compared to the other study streams. Ten genera were recorded in Eholié Stream, and 9 genera in Noé Stream. Soumié Stream and Bia Rivers recorded respectively 8 and 7 genera of Chironomidae. The generic richness found in this study is low compared to those reported in low order streams in Brazilian Atlantic forest (Roque *et al.,* 2007).

Chironominae subfamily was the dominant group at the different stations except station Eh2 (Ehania Stream) and S2 (Soumié Stream) where Orthocladiinae was most abundant. Stations Eh2 and S2 are characterized by high vegetable debris in the substrate. This could explain the high abundance of Orthocladiinae in these stations as it was showed by Vieira *et al.* (2012) in Chironomidae studies in South Occidental Amazon. Subfamily Tanypodinae was most abundant in Banco Stream located in Banco National Park. The preference of Tanypodinae larvae to environment, with predominance of mud (McLarnon; Carter, 1998), possibly explains the higher abundance found for this group in the sampled this stream. This subfamily is known to be predominant in natural areas and related with environmental conditions characteristic of less impacted areas (Roque *et al.,* 2007; Fonseca-Leal *et al.,* 2004).

Regarding genera, *Tanytarsus* (Chironominae) was the dominant taxon in the upstream stations of Bia and Agnéby River, while *Polypedilum* (Chironominae) was the dominant taxon at the other stations. These genera are widely distributed worldwide due to the adaptation to a wide variety of environmental conditions (Nessimian and Henriques-Oliveira, 2005; Higuti and Takeda, 2002). The larvae of these genera may occupy different types of substrate under different flow condition (Rosin *et al.,* 2009). Indeed, the Tanytarsus genus predominantly occurred in litter, both in riffle and pool areas (Sanseverino and Nessimian, 2001).

Overall, generic richness was higher in rainy season in rivers Agnéby and Bia, while the inverse was observed for Ehania, Eholié, Noé, and Soumié streams where the richness was higher in dry season. Meanwhile, this seasonal richness was not significantly distinct in each sampling station. This is usually observed for the benthic macroinvertebrates in tropical areas (Camara *et al.,* 2012).

It is known that the spatial distribution of aquatic insect larvae is closely related to morphological and physiological adaptation to the physical characteristics of the habitats although some species may exhibit higher plasticity in relation to the type of habitat they occupy (Roque *et al.,* 2007; Pinha *et al.,* 2013). This is usually observed for various members of Chironomidae family, both in relation to the substrate they occupy and to water characteristic (Sanseverino and Nessimian, 2001). According to the correspondence analysis, the major factors acting upon the chironomid fauna abundance and distribution were current flow, substrate characteristics, and water mineralization level. Speaman's correlation analysis revealed that the abundance of the Chironominae genera such as *Nilodorum* and *Stenochironomus* was positively correlated with water temperature, while genus *Stictochironomus* was negatively correlated with this variable. It clearly shows that genara in the same subfamily can have different preference environmental variable. The abundance of genus *Ablabesmyia* (Tanypodinae) was negatively correlated with dissolved oxygen level. Conductivity, total dissolved solids and pH had positive correlation with Chironominae genera (*Stenochironomus*, *Stictochironomus*, and *Tanytarsus*), while these variables were negatively correlated with Orthocladiinae genera (*Nanocladius* and *Cricotopus*).

Conclusion

This was the first research on Chironomidae communities in the Southeast Côte d'Ivoire coastal lotic systems. The results provide valuable initial insight to the habitat variables influencing chironomid larval distribution in this region. Chironomidae can be used as a potential instrument in future ecology studies in lotic systems of Southeast Côte d'Ivoire.

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