Structure of benthic macroinvertebrates population in an area of Mopoyem Bay (Ebrie Lagoon, Côte d’Ivoire) exposed to the discharge of a fish farm effluents

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Abstract Discharges of untreated effluent from fish farming into the aquatic environment are a practice that can affect local biodiversity. This study was conducted to characterize, in the Ebrie Lagoon, the structure of benthic macroinvertebrates inhabiting an environment exposed to effluent discharges from fish farms. The benthic macroinvertebrates were collected with a Van Veen grab seasonally between August 2016 and July 2017 at the effluent discharge point in the lagoon and at a reference station out of anthropogenic activities. Identification of organisms was done using specialized keys. The results revealed that the proportion of tolerant macroinvertebrates is relatively high (47.74%) at the point of discharge of fish farming effluents into the Ebrie Lagoon. While at the reference station, macroinvertebrates population is dominated by sensitive and medium-sensitive taxa (93.53%). The benthic macroinvertebrates population, influenced by seasonal variations, exhibits peaks of abundance and diversity during the rainy seasons, while during the dry seasons, they strongly decline. Fish farming effluents dumped in Ebrie Lagoon lead to structural modifications of the local benthic macroinvertebrates population. These disturbances are intensified in dry seasons and attenuated in rainy seasons. This information should be taken into account in any decision to promote the responsible practice of fish farming and the sustainable management of water resources exploited for fish farming purposes.

Keywords Aquaculture · Consequences · Benthic fauna · Tropical lagoon · West of Africa

Introduction

The discharge of untreated wastewater into the aquatic environment is a problem that affects all countries of the world. These are mainly domestic or industrial discharges or releases from other activities such as fish farming. The development and intensification of fish farming has raised many environmental concerns because of the nature of the waste produced (UICN 2007) and the consequences that it could have on the balance of aquatic ecosystems (Cao et al. 2007; Bjorn 2007; Halwart et al. 2007; Price et al. 2015).

The discharge of fish farming effluent into the aquatic environment is a topical issue in Côte d’Ivoire, particularly in the Ebrie Lagoon where many ponds are exploited on the banks for the intensive production of Oreochromis niloticus (MIPARH 2009). These farms are exploited unfortunately without environmental provisions, and their effluents are discharged into the lagoon without prior treatment (Toulé et al. 2017; Yoboué et al. 2018a). This is a problem because the effluents emitted by the ponds, sometime, contain non-ingested
food debris, metabolic compounds, bacteria, and sometimes chemicals (Legendre et al. 1987; Gorlach-Lira et al. 2013; Schlumberger and Girard 2013). The accumulation of these organic and chemical compounds in the receiving environment can lead to changes in environmental characteristics and cause significant changes in aquatic life, especially in the local benthic fauna. These organisms, however, play a major role in the functioning of aquatic environments. They are involved in the recycling of organic matter and in the process of self-purification of water. They are above all an essential link in the trophic chain of aquatic ecosystems (Gnohossou 2006).

The environmental studies carried out at the Ebrie Lagoon have for the most part focused on the damage caused by the discharge of domestic wastewater and industrial (Dongo et al. 2013) or agricultural effluents (Koffi et al. 2014). However, no study has addressed the question of the impact of discards from fish farms in this environment. This study aims to characterize the population of benthic macroinvertebrates exposed to the discards of a fish farm in the Ebrie Lagoon.

Material and methods

Description of the study area

Mopoyèm Bay is located in the west of Ebrie Lagoon specifically in Sector V on the north shore side between 4°45'1 and 4°46'4 longitudes West and between 5°30'6 and 5°31'8 latitudes North (Fig. 1). This bay with a catchment area of 14.45 km² (Varlet 1978; MINÉF 1999) is located in a locality influenced by a humid Attiean equatorial climate with four seasons, two dry seasons (short dry season: August and September and long dry season: December, January, February, and March) and two rainy seasons (short rainy season: October and November then long rainy season: April, May, June, and July) (Savane and Konare 2010). The waters of this bay are also influenced by the floods and decreases of a small coastal river (Kpapkidje). Described as oligohaline and not polluted by Pagano and Saint-Jean (1988), the waters in this bay are characterized by a relatively low salinity varying according to the seasons and with a temperature oscillating around 24.0 °C in the rainy season and 30.0 °C during the dry season (Illits 1984).

Mopoyèm Bay permanently receives the effluents of a fish farm installed on its banks. This farm has 13 concrete ponds for the reproduction and rearing of fish and about 20 ponds for pre-growing and growing phases of Nile tilapia Oreochromis niloticus. A pipeline network collects effluents from different concrete ponds and earthly ponds before discharging through a main channel to the bay.

Two sampling stations were chosen. The first station (RP: 5°41'9,107 N - 3°85'8,720 W) is under influence of fish farm discharges. The second station is the reference station (RS: 5 ° 30'3,318 N - 4 ° 47'2,102 W). This station is out of anthropogenic activities and point contamination.

Sampling and identification of the benthic fauna

Four sampling campaigns were carried out following the seasons from August 2016 to July 2017 precisely in the months of August (short dry season), November (short rainy season), February (long dry season), and July (long rainy season). Benthic organisms were sampled using a Van Veen grab of 0.0250 m². Ten (10) collections were made at each station. The benthic organisms were subsequently sorted and stored in pill containers and fixed in formaldehyde 10% solution. The identification of macroinvertebrates, carried out with a binocular magnifying glass, has been stopped at the family level to avoid systematic errors. Binder (1957), Dejoux et al. (1981), and Tachet et al. (2010) keys were used for identification.

Data analysis

Shannon diversity index (H') and equitability of Pielou (E) were used to measure and compare the taxonomic composition at each station. Sorensen (β) index was used to appreciate the similarity of benthic macroinvertebrates taxa between the two stations. The main families are those with an occurrence greater or equal to 5% of the total number of benthic macroinvertebrates harvested at each station.

Results

Taxonomic composition of benthic macroinvertebrates fauna

During the study period, 4 phyla, 8 classes, 18 orders, 27 families, and 973 individuals of benthic macroinvertebrates
were harvested (Table 1). Arthropods are the most diverse group with 3 classes, 11 orders, and 16 families. They are followed by annelids includes 2 classes, 4 orders, and 6 families. Molluscs are represented by 2 classes, 2 orders, and 4 families, while the cnidarians branch, the least diversified group, includes 1 class, 1 order, and 1 family. Insects with a 33.50% share are the most abundant and diverse group. Coleoptera, Dermaptera, Diptera, Ephemeroptera, Hemiptera, and Odonata are the different orders of the insect class. In terms of diversity, the orders of the Hemiptera, Odonata, and Diptera come first with 2 families each, then followed the order of the Ephemeroptera, Coleoptera, and Dermaptera with each 1 family. In terms of abundance, the class of insects includes, in order of importance, Baetidae, Chironomidae, Libellulidae, Lestidae, Veliidae, Belostomatidae, Forficulidae, Dytiscidae, and an unidentified family. The two studied stations have in common 11 families constituted by Thiaridae, Nereididae, Lysaretidae, Tetragnathidae, Chironomidae, Forficulidae, Baetidae, Veliidae, Belostomatidae, Dytiscidae, and Lestidae. Concerning susceptibility of benthic macroinvertebrates organisms to pollution, one sensitive family (S), 7
tolerant families (T), and 19 families of medium sensitivity (M) have been identified (Table 1).

At the lagoon discharge of fish farm point, 17 macroinvertebrate families were identified, while 21 families were identified at the reference station. The station exposed to fish farm discharge is therefore less diversified than that of the reference station. Shannon index \( (\text{H} = 2.29) \) and equitability of Pielou \( (E = 0.81) \) at the discharge point of fish farm effluents into the Ebrie Lagoon are low compared to those \( (\text{H} = 2.47 \text{ and } E = 0.81) \) obtained at the reference station. But, the Sorensen index \( (\beta = 0.58) \) shows a slight similarity between the stations (Table 2).

Spatial distribution of benthic macroinvertebrate groups

At the point of discharge into the lagoon of fish effluents (PR), Thiaridae (34%), Chironomidae (28%), Tubificidae (18%), Tetragnathidae (13%), and Lumbricidae (7%) are mainly found (Fig. 2).

With regard to the Mopoyém (RS) reference station, the main families are Gammaridae (32%), Corophidae

### Table 1

| Phylum      | Classes     | Orders       | Families    | Sensitivity | Abundance per station |
|------------|-------------|--------------|-------------|-------------|-----------------------|
|            |             |              |             |             | RP        | RS        |
| Cnidarians | Hydrozoa    | Hydroidea    | Clavidae    | M           | 0         | 1         |
| Mollusca   | Bivalvia    | Veneroida    | Donacidae   | M           | 0         | 52        |
|            | Gastropods  | Caenogastropoda | Thiaridae   | M           | 88        | 9         |
|            |             |              | Neritidae   | M           | 5         | 0         |
|            |             |              | Skeneopsidea | M           | 1         | 0         |
| Annelids   | Clitellata  | Haplotaxida  | Tubificidae | T           | 46        | 0         |
|            |             |              | Lumbricidae | T           | 20        | 0         |
| Polycheta  | Aciculata   | Nereididae   | T           | 13          | 19        |
|            | Eunicida    | Lysaretidae  | T           | 4           | 8         |
|            | Phylloocida | Nephytidae   | T           | 8           | 0         |
|            |             |              | Sigalionidae| T           | 5         | 0         |
| Arthropods | Arachnida   | Tetragnathida| T           | 33          | 7         |
|            |             | Trombidiformes| Hydrachnidae| M           | 0         | 4         |
| Insect     | Diptera     | Chironomidae | T           | 73          | 13        |
|            |             | Unidentified | M           | 0           | 3         |
|            | Dermoptera  | Forficulidae | M           | 9           | 8         |
|            | Hemiptera   | Veliidae     | M           | 13          | 17        |
|            |             | Belostomatida| M           | 16          | 13        |
|            | Ephemeroptera| Baetidae    | S           | 9           | 78        |
|            | Odonata     | Libellulidae | M           | 0           | 34        |
|            | Coleoptera  | Dytiscidae   | M           | 2           | 6         |
| Malacostraca| Amphipoda  | Gammaridae   | M           | 0           | 148       |
|            |             | Corphidae    | M           | 0           | 82        |
|            | Decapoda    | Palaemonidae | M           | 0           | 27        |
|            | Isopoda     | Sphaeromatida| M           | 0           | 62        |

4  8  18  27  354  619

RP: point of discharge of fish farm effluent in Ebrie Lagoon, RS: reference station, M: medium, S: sensitive, and T: tolerant
(18%), Baetidae (17%), Sphaeromatidae (14%), Donacidae (11%), and Libellulidae (8%) (Fig. 3).

The spatial distribution of benthic macroinvertebrates by their sensitivity to pollution is shown in Fig. 4. The benthic macroinvertebrates population is represented by 48% of tolerant organisms, 50% of organisms with medium sensitivity, and 2% of organisms sensitive to the discharge point (PR) in the lagoon of effluents emitted by ponds. However, the Mopoyème (RS) reference station is populated with 6% tolerant organisms, 81% medium sensitivity organisms, and 13% susceptible organisms.

The station at the discharge point of fish farming effluents (PR) has a high proportion (47.74%) of tolerant organisms (mainly represented by Chironomidae, Tubificidae, and Lumbricidae families), while the reference station has more than 93.53% of sensitive organisms constituted by Baetidae family and medium-sensitive organisms (mainly represented by Gammaridae, Corophiidae, Sphaeromatidae, Donacidae, and Libellulidae families).

Influence of seasons on abundance and taxonomic richness

Figure 5a and b show seasonal variations in abundance and taxonomic richness, respectively. At the point of discharge of fish farm effluents in the lagoon, the abundance and taxonomic richness are 86 and 9 in the long dry season, 82 and 11 in the short dry season, 99 and 14 in the long rainy season then 87 and 14 in the short rainy season, respectively. At the reference station level, abundance and taxonomic richness are 57 and 12 in long dry season, 57 and 13 in short dry season, 285 and 21 in long rainy season, and 220 and 18 in short rainy season, respectively. Abundance and taxonomic richness vary greatly when moving from one season to another at the level of the two stations studied. These two parameters are higher in rainy seasons than in dry seasons.

Discussion

Results of benthic macroinvertebrates population structure show that the abundance and taxonomic richness at the point of discharge of fish farming effluents are small compared to those of the reference station. Certain taxa such as the order of the Amphipods (Gammaridae and Corophiidae), Isopoda (Sphaeromatidae), Hemiptera, Coleoptera (Dytiscidae), and Odonata (Libellulidae) are well represented at the reference station but absent at the level of discharge point of fish farming effluents. Tolerant organisms such as Tubificidae, Chironomidae, and Lumbricidae are the most abundant at the point of release of fish effluents, while at the reference station, insects and crustaceans dominate. The taxonomic composition at the two stations would be dependent on the environmental conditions specific to each of them. Indeed, at the point of discharge of fish effluents, the accumulation in

| Stations | N  | Tr |  E    |  H'  |  β    |
|-----------|----|----|-------|------|-------|
| RS        | 619| 21 | 0.8123| 2.473| 0.57895|
| RP        | 354| 17 | 0.8067| 2.286|        |

Table 2 Abundance (N), taxonomic richness (Tr), equitability (E), Shannon (H'), and Sorensen (β) index of two sampling stations.
the sediments of non-ingested food and metabolic compounds (feces, urea, and mucus excreted by farmed fish) drained by the effluents to the receiving environment would constitute a stock of attractive food for molluscs and annelids which are scavenger and omnivorous organisms (Díaz-Castaneda and Safran 1988; GRETIA 2009). The decomposition of these organic materials would favor a nutrient enrichment of the environment with consequent local organic pollution. Such conditions are generally unfavorable for the survival of highly sensitive benthic macroinvertebrates such as Ephemeroptera and some Coleoptera. Organisms that are more tolerant to organic pollution and require less oxygen, such as annelids and Chironomidae (Olomukoro and Ezemonye 2006) are able to proliferate under particular conditions such as the point of discharge of fish farm effluents. According to Moisan and Pelletier (2008), when the environment is disturbed or the environmental conditions become unfavorable, the most sensitive organisms struggle to survive. They decrease in favor of the most resistant. For this purpose, insects that are generally a group of highly sensitive to organic pollution (Azrina et al. 2006) with the exception of Chironomidae regress in the environment because of the high organic load of sediments exposed to fish farm releases. Fagrouch et al. (2011) also noted in their work at Oued Za (Eastern Morocco) that the number of insects was low at the stations receiving urban effluents compared to those that did not receive them. The relatively large number of organisms from the families of Tubificidae and Chironomidae in the environment receiving fish farm releases indicates disturbances caused by the organic matter transported by the effluents. These pollution indicator organisms are the common inhabitants of disturbed environments, rich in nutrients and oxygen deficient according to Olomukoro and Ezemonye (2006).

The Shannon diversity index and equitability at the discharge point of fish farming effluent in lagoon are relatively low compared to those in the reference station. The population of macroinvertebrates in the receiving environment of fish farm effluents is less diversified than that of the reference station. The value of the Sorensen similarity index obtained shows that there is a clear similarity between the two stations. The 25 families record in the two stations; there are 11 families common to both stations. Ten (10) families were found exclusively at the reference station against six at the point of discharge into the lagoon of the effluents emitted by the ponds. The two stations, therefore, have more taxa in common. Effluents from fish ponds would have caused less disturbance to benthic macroinvertebrates...
population structure at the receiving environment. Indeed, a large part of the organic matter of the effluents would have decanted in the evacuation channels before the effluents reach the lagoon. Thus, fish farm effluents that emerge from the drainage channel and discharged into the lagoon would probably be less loaded with organic debris and solid particles. It should be noted that the changes observed on the benthic macroinvertebrates population at the effluents discharge point in this study are less important than those obtained by Yoboué et al. (2018b, 2018c) at the level of a fish farm operating floating cages in the Aghien lagoon and Acadjas in Mopoyèm Bay, respectively.

The seasonal cycle shows that the population of benthic macroinvertebrates varies considerably from one season to another at the two stations. In dry seasons, there is a less abundant and poorly diversified macroinvertebrates population. In rainy seasons, however, there is an increase in abundance and diversity. These variations can be explained by the fact that rains and floods during rainy seasons lead to better living conditions. This is the acceleration of the productivity of aquatic ecosystems following the supply of nutrients (Agblonon et al. 2017) and the dilution of polluted water by the addition of runoff water (Mucheso et al. 2017). In general, changes in the structure of aquatic organisms (Albaret and Ecotin 1990; Khalkie et al. 2004; Benabdellouahad 2006; Niamien-Ebrotté et al. 2013; Appiah et al. 2018) particularly benthic macroinvertebrates (Djiriéoulou et al. 2017; Sanz 1986; Sanogo et al. 2014; Menbohan et al. 2010; Adandedjan et al. 2013) are manifested by numerical changes in the abundance and species richness of the population.

**Conclusion**

The benthic macroinvertebrates population of the lagoon area exposed to fish effluent discharge that includes a high proportion of organic pollution tolerant organisms. They are mainly annelids of Tubificidae and Lumbricidae family and also insects of Chironomidae family. Abundance and taxonomic richness vary considerably from one season to another. They are higher in rainy seasons than in dry seasons. In addition, the Sorensen index ($\beta = 0.57895$) reveals that there is a clear similarity between the macroinvertebrates population at the level of the effluent receiving area and that of the reference station.

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**Compliance with ethical standards**

**Conflict of interest** The authors declare that they have no conflict of interest.
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