World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Identification of fish behaviours in littoral habitats of Lake Buyo (south-west Ivory Coast) using video surveillance

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World Journal of Advanced Research and Reviews, 2024, 22(03), 938–953

Publication history: Received on 01 May 2024; revised on 09 June 2024; accepted on 11 June 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.22.3.1680

Abstract

Video surveillance is a non-extractive and less disruptive method of observing fish in their natural environment. Increasingly used, this technique makes it possible to describe the behaviour of fish in their habitat. In Côte d'Ivoire, the use of waterproof cameras for ichthyological purposes is still not widespread. This study proposes to use video surveillance to identify the different behaviours performed by fish in the littoral habitats of the Buyo dam lake. The objective is to know the mode how fish use the littoral habitats of Lake Buyo in order to provide managers with important data for developing programmes to preserve and manage these environments. Four unbaited camera systems were deployed at each station between 7 am and 6 pm. In the laboratory, various criteria were used to identify the behaviour of the fish. The results show that 8 species of fish frequented the littoral habitats of Lake Buyo to feed, reproduce and protect themselves from predators. Feeding (62.70%) was the most frequently observed activity, followed by reproduction (32.32%). The Dera and Pk15 stations recorded the highest number of species and behaviours. These behaviours varied according to species; *Coptodon zillii* stood out by displaying the highest average frequency (32.12 activities/day) of all types of behaviour observed in fish. The data from this study are essential for developing strategies to effectively conserve coastal areas in order to ensure the long-term survival of the species.

Keywords: Fish Populations; Ecological Behaviors; Littoral Habitats; Video Surveillance; Lake Buyo

1. Introduction

Littoral zones are essential habitats for many fish species [1. 2. 3]. The structural complexity and heterogeneity of littoral habitats are known to promote biodiversity, production and food web complexity [4. 5-8]. Most fish in lake environments use the littoral zone on a diurnal, seasonal or ontogenetic scale [9. 10. 11] for feeding, spawning, rearing or as a refuge habitat from predators [12. 13. 2]. However, despite their importance to Lake Buyo, littoral zones are subject to numerous anthropogenic pressures that can jeopardize not only the natural balance of the environment but also fish stocks [14. 15]. These disturbances can lead to changes in the behavior of fish species, with general effects on the distribution and abundance of fish populations [16]. They can also trigger the migration of certain species during periods of high and low water [17]. Understanding how fish use coastal habitats therefore requires special attention to mensure the protection and sustainable management of these environments. For this, it is necessary to implement sampling strategies that take into account the most relevant sampling frequencies to best monitor fish behavior [18]. Indeed, the habitats in which fish live are often difficult to access, creating unique challenges for sampling strategies aimed at assessing habitat use and estimating demographic trends for the management of freshwater fish and their environment [19]. However, the methods generally used (fishing using extractive fishing gear) for the behavioral study of fish do not make it possible to monitor and better describe the behavior of fish in the habitats they colonize to meet their needs [20. 21. 19]. However, other methods such as fish observation using underwater cameras solve many of the

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problems associated with sampling in difficult-to-access habitats and offer the possibility of collecting data at a level of detail never before achieved in fish habitats [22]. Although not without its limitations [3] underwater video makes it possible to determine which species use habitats, their temporal patterns of use and their behaviors in the habitat. The main objective of this work is to know the mode how fish use the littoral zones of Lake Buyo. More specifically, it aims to: (1) make an inventory of the different fish species that use the littoral habitats of Lake Buyo to fulfill their needs; (2) identify the different behaviors performed by fish in the littoral habitats of Lake Buyo; (3) determine the frequency of the types of behaviors performed by fish in the littoral habitats of Lake Buyo.

2. Materials and methods

2.1. Study environment

Lake Buyo is located in the southwest of Côte d'Ivoire, between 06°14' and 07°03' north latitude and 06°54' and 07° 31' west longitude (Figure 1). It comes from a hydroelectric dam built on the Sassandra River, 4 km downstream from the confluence with the N'Zo River, on the edge of the Taï National Park and drowning approximately 8,400 hectares of forest [24]. This lake covers an area of 920 km^2 with a catchment area of 75,000 km^2. The hydrological conditions of Lake Buyo during the year 2020 are marked by a period of high water (September to February) and a period of low water (March to August). Four sampling stations were chosen in the part of the lake which includes the Taï National Park based on accessibility: PK15 (07°08'031''N and 06°90'863''W), PK28 (07°00'490''N and 06°90'217''W); Dera (07°03'599''N and 06°96'442''W) and Beablo (06°91'654'' N and 07°06'554'' W). The stations were characterised according to the protocol implemented by IFREMER on the AMBIO programme (Pelletier *et al.*, 2016). Thus, stations Dera and Pk15 are habitats characterised by dense, tall seagrass beds, station Beablo is characterised by a sparse seagrass bed and station Pk28 is characterised by a short seagrass bed..

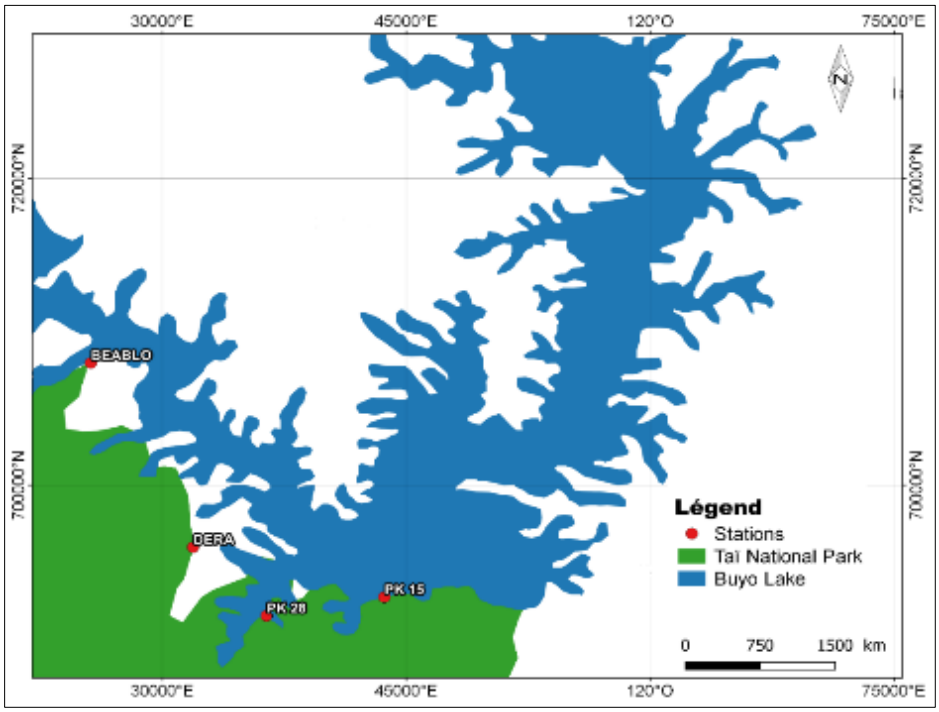


Figure 1 Location of sampling stations in Lake Buyo (Ivory Coast).

2.2. Data collection

The present study was carried out between January 2020 and December 2020. The behavioral study of fish in the littoral habitats of Lake Buyo was carried out using three observation devices separated from each other by at least 20 meters [22]. Each device consists of a camera (Brand APEXAM; model M80; number of pixels 20 MP; resolution 4K; type of lens wide angle) and a support on which the camera is fixed horizontally (Figure 2), thus facilitating the identification of fish present in the field of the cameras [25]. Before deploying the recording devices, the indicator light on each camera was sealed with black adhesive tape to prevent the flashing light from affecting fish behavior. The device was deployed

manually and video recordings lasted 1h30 min. After the 1h30 minutes of recording, the devices were removed to replace the batteries. At each station, four deployments per device were carried out per day, two days per month.

2.3. Data analysis

In the laboratory, video sequences, previously recorded on DVD disks, were viewed with a computer using players (Gom Player and VLC). These players are capable of low-speed playback and image optimization (contrast, brightness and color saturation) to facilitate fish identification [26]. Fish were identified using the identification keys of Paugy et al. [27 a and 28 b] and species names were updated in Fishbase [29]. The various behaviors performed by the fish were identified using a number of criteria : Fish spawning behaviour has been defined according to the activities listed by Lévêque & Paugy [30], Gophen [31] et N'Dri [15]. These activities are:

- Nest Building ;
- Egg And Larva Guarding ;
- Egg-Laying Behavior;
- Egg Fertilization;
- Spawning Aggregation.

As for fish feeding behaviors, they were defined according to the activities proposed by Soria [32] and Sheaves et al. [22]:

- Collecting food from seagrass beds,
- Bottom feeding,
- Foraging on and in the water column;

Leak or avoidance behaviors defined according to the activities observed by Munsch et al. [33] and Sheaves et al. [22]:

- Moving away from prey when approaching predators ;
- Camouflage of prey when approaching predators.

Predation-related behaviors are described according to the activities proposed by Savino & Stein [34]:

- Seeking: when the animal explores the environment without orienting itself directly towards the prey;
- Following: when the animal moves slowly towards the prey;
- Pursuit: when the animal follows the prey at high speed;
- Attack: when the animal strikes the prey;
- Capture: when the animal engulfs and handles its prey.

2.4. Statistical analysis

2.4.1. Frequency (F) of behavior types by species

The frequency (F) of behavior types by species is calculated using the following formula:

$$F = \frac{Nc}{t}$$

Where: Nc = Number of times a behavior occurs

t = Time of observation.

2.5. Kruskal-Wallis and Mann-Whitney tests

Non-parametric Kruskal-Wallis and Mann-Whitney tests were used to determine the degree of significance of frequency between stations and between periods (high and low water). Tests are significant at $p < 0.05$. These tests were performed using STATISTICA software version 7.1.

3. Results

3.1. Species observed in the littoral habitats of Lake Buyo

The installation of unbaited cameras in the littoral zone of Lake Buyo made it possible to observe eight species of fish which frequented the littoral zones of Lake Buyo to carry out different types of behavior (Table 1). These are: the species *Brycinus* sp, *Coptodon zillii*, *Enteromius macrops*, *Hemichromis bimaculatus*, *Hemichromis fasciatus*, *Lates niloticus*, *Oreochromis niloticus* (Table 1). At stations Beablo (habitat dominated by a sparse or even absent seagrass) and Pk28 (habitat dominated by a short seagrass), four fish species were recorded per station (Table 1). On the other hand, at stations Dera and Pk15 (habitats characterized by dense, tall seagrass), five fish species were observed per station (Table 1). The figure 2 shows the list of species most frequently observed using unbaited cameras.

Table 1 List of fish species observed in littoral habitats using unbaited cameras during the period January to December 2020.

Species	**Beablo**	**Dera**	**Pk28**	**Pk15**
Brycinus macrolepidotus	+	+	-	-
Brycinus sp.	+	+	-	-
Coptodon zillii	+	+	+	+
Enteromius macrops		+	+	+
Hemichromis bimaculatus	-	-	-	+
Hemichromis fasciatus	-	-		+
Lates niloticus	-	-	+	-
Oreochromis niloticus	+	+	+	+
Total 08	04	05	04	05

+ : presence ; - : absence

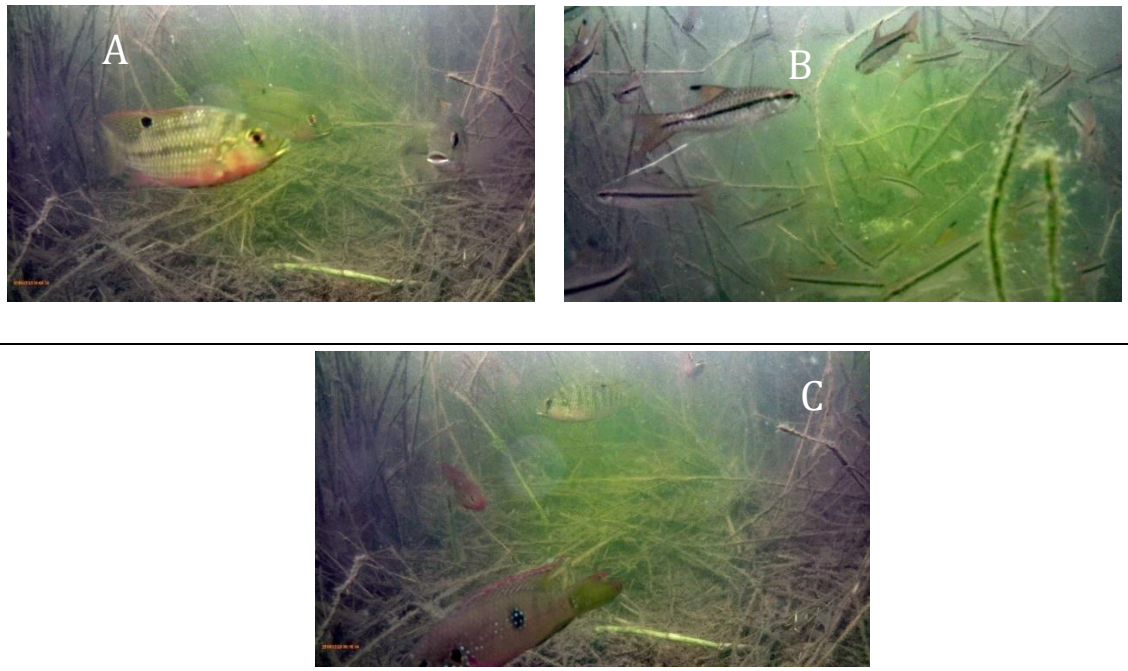


Figure 2 list of some of the fish species observed via the video surveillance system
A : *Coptodon zillii* ; B : *Enteromius macrops* ; C : *Hemichromis bimaculatus*

3.2. Different behaviors performed by fish in the littoral habitats of Lake Buyo

The present study identified four types of behavior performed by fish in the field of view of the cameras deployed (Table 2). These include feeding, leak, predation and reproduction. Feeding was characterized by foraging on seagrass beds, in the water column and on the substrate (Table 2). Collecting food from seagrass beds (67.19 %) was the most frequently observed feeding activity (Table 2). Reproduction was defined as parental guarding of eggs and larvae, nest building and egg laying and fertilization. Nest guarding is the most observed activity, with a rate of 59.61 % (Table 2). This is followed by nest building (30.57 %) and egg laying and fertilization (9.82 %) (Table 2). As for leak, this involved moving away from and camouflaging prey as it approached predators. Distancing of prey from approaching predators was the most common, at 83.33 % (Table 2). Predation was characterized by the search and tracking of prey by predators. The search for prey by predators was the most observed activity at 77.77 % (Table 2).

Table 2 Proportion of behavior types performed by fish at all stations

Observed behaviors	Observed criteria	Proportions (%)
Eating behavior	Collecting food from seagrass beds	63.19
	Feeding in the water column	8.85
	Feeding on bottom substrate	27.96
Breeding behavior	Parental care	59.61
	Nest building	30.57
	Egg laying and fertilization	9.82
Leak behavior	Distance	83.33
	Camouflage	16.67
Predatory behavior	Prey search	77.77
	Prey tracking	22.23

Among the behaviors observed in Lake Buyo, feeding behavior is the most observed activity in the field of view of the deployed cameras, with a rate of 62.70 % (Figure 3). This behavior is followed by reproductive behavior at 34.32 % (Figure 3). Leak behavior accounts for 1.98% and predation behavior for 0.99 % of all behaviors observed in Lake Buyo. At the Beablo (habitat characterized by a sparse or even absent seagrass bed) and Pk28 (habitat characterized by a short seagrass bed) stations, two behaviours (feeding and reproduction) were observed (Table 3). On the other hand, at stations Dera and Pk15 (habitat characterized by a dense, tall meadow), four behaviors (feeding, reproduction, leak and predation) were observed (Table 3).

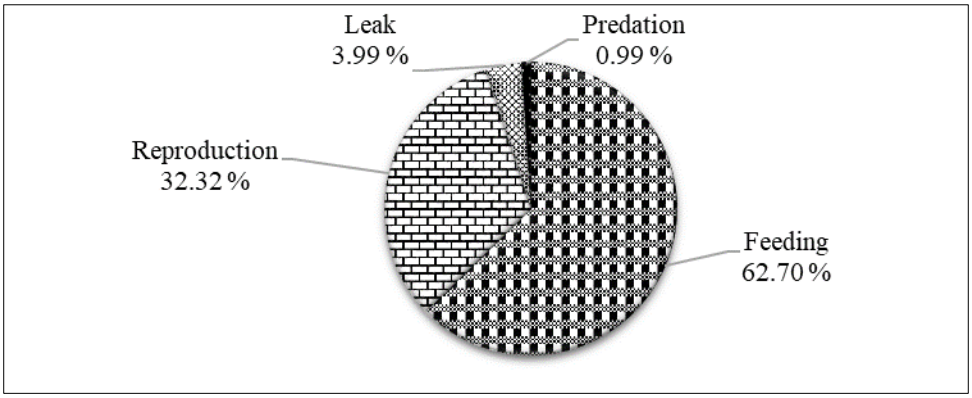


Figure 3 Proportion of behavior types observed in the littoral zone of Lake Buyo

Table 3 Types of behaviour observed by station

Behavior	Beablo	Dera	Pk28	Pk15
feeding	+	+	+	+
leak	-	+	-	+
predation	-	+	-	+
reproduction	+	+	+	+
Total 04	02	04	02	04

3.3. Types of behavior by species

Our observations show that the species *Brycinus macrolepidotus* frequents this environment to feed. On the other hand, *Enteromius macrops*, *Brycinus sp* and *Oreochromis niloticus* frequent lake habitats in the littoral zone of Lake Buyo to feed and take shelter from predators (Table 4). Predatory behaviour was observed in *Hemichromis fasciatus* and Lates niloticus. *Coptodon zillii* frequents these habitats for feeding, reproduction and shelter from predators (Table 4). The species *Hemichromis bimaculatus* our observations have shown that it frequents these habitats to feed and breed. (Tableau 4). The analysis shows that 06 species frequented the littoral habitats of Lake Buyo for feeding, 04 species for shelter, 02 species for reproduction and 02 species showed predation behaviour (Table 4).

Table 4 Types of fish behaviour in Lake Buyo.

Species	feeding	Leak	Predation	Reproduction	Total
Brycinus macrolepidotus	+	-	-	-	01
Brycinus sp.	+	+	-	-	02
Oreochromis niloticus	+	+	-	-	02
Enteromius macrops	+	+	-	-	02
Hemichromis fasciatus	-	-	+	-	01
Lates niloticus	-	-	+	-	01
Coptodon zillii	+	+	-	+	03
Hemichromis bimaculatus	+	-	-	+	02
Total	06	04	02	02	

3.4. Average frequency of realisation behaviour by each species type

3.4.1. Total mean frequency

Analysis of the average frequency of types of behavior performed by fish in the littoral habitats of Lake Buyo showed that *Coptodon zillii* performs the highest frequency (32.12 ± 1.17 activities/day) (Figure 5). It is followed by *Oreochromis niloticus* (16.28 ± 1.57 activities/day), *Enteromius macrops* (7.91 ± 0.67 activities/day) and *Brycinus macrolepidotus* (4.66 ± 0.44 activities/day). The species *Lates niloticus* recorded the lowest average frequency with 0.28 ± 0.03 activities/day. Significant differences were observed between the mean frequency values of the types of behavior performed by species (Kruskal-Wallis test; $p < 0.05$).

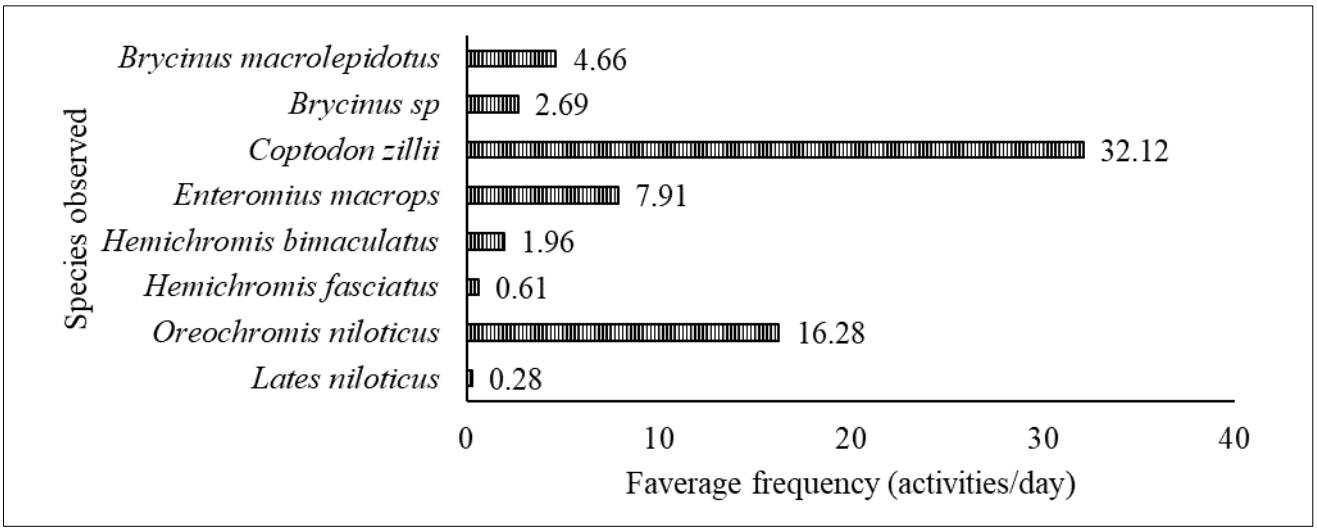


Figure 4 Average frequency of activities carried out by each species in all littoral habitats from January 2020 to December 2020**.**

3.4.2. Spatial variation in mean frequency of behavior types performed by species

For *Coptodon zillii*, the average frequency of observed behavior types is higher (8.92 ± 0.67 activities / day) at the Dera station and lower at the Beablo station (6.52 ± 0.50 activities / day) (Figure 6). However, the differences observed between the average frequencies achieved by this species at each station were not significant ($p > 0.05$). Among the various behaviors performed by this species, feeding was the most common (53.73 - 56.03 %) at all stations, followed by breeding (43.96 - 46.26 %) (For *Oreochromis niloticus*, the highest mean frequency (4.77 ± 0.95 activities / day) was recorded at the Dera station, and the lowest (3.08 ± 0.63 activities / day) at the Beablo station (Figure 6). However, the differences between stations were not significant ($p > 0.05$). Feeding behavior is the most common activity performed by this species at all stations (90.12 -100 %) (Figure 6).

Enteromius macrops recorded the highest average frequency (3.25 ± 0.78 activities / day) of behavior types at station Dera, and the lowest (1.06 ± 0.17 activities / day) at station Beablo. There was no statistically significant difference between the average frequency recorded at the different stations (Kruskal-Wallis test ; $p > 0.05$). The results of this study show that feeding is the activity most observed in this species at almost all stations (64.58 – 100 %). This was followed by escape, observed at stations Pk28 and Pk15 (17.24 - 35.41 %) (Figure 7). In *Brycinus macrolepidotus*, the average frequency of behavior types is high (3.42 ± 0.56 activities / day; 100 %) at the Beablo station (Figure 6). At the Dera station, the average frequency was 1.23 ± 0.16 activities / day, i.e. 100 % (Figure 6). At stations Pk28 and Pk15, this species did not exhibit any behavior. The Kruskal-Wallis test shows a significant difference between the Beablo station and those at Pk28 and Pk15 ($p < 0.05$).

Hemichromis fasciatus recorded an average frequency of 1.29± 0.16 activities / day, i.e. 100 % (Figure 6) of the behavior observed at station Pk15. However, no activity was observed at any of the other stations. Difference s between stations were not significant (Kruskal-Wallis test ; $p > 0.05$).

With regard to *Lates niloticus*, predation behavior was only observed at the Dera station, with an average frequency of 0.84 ± 0.16 activities / dayr (100 %) of activities carried out (Figure 6). There was no significant difference between stations (Kruskal-Wallis test; $p > 0.05$).

Brycinus sp, performed the highest mean frequency (2.68 ± 0.44 activities / day) at the Beablo station, followed by the Dera station with a mean frequency of 1.57 ± 018 activities / day (Figure 6). Significant differences were observed between stations (Kruskal-Wallis test ; $p < 0.05$).

As for *Hemichromis bimaculatus*, the mean frequency (1.96 ± 0.21 activities / day) was only recorded at station Pk15 (Figure 6). The Kruskal-Wallis test indicates significant differences between stations ($p < 0.05$). Feeding behavior is the most common (66.66 %) for this species, followed by reproduction (33.34 %).

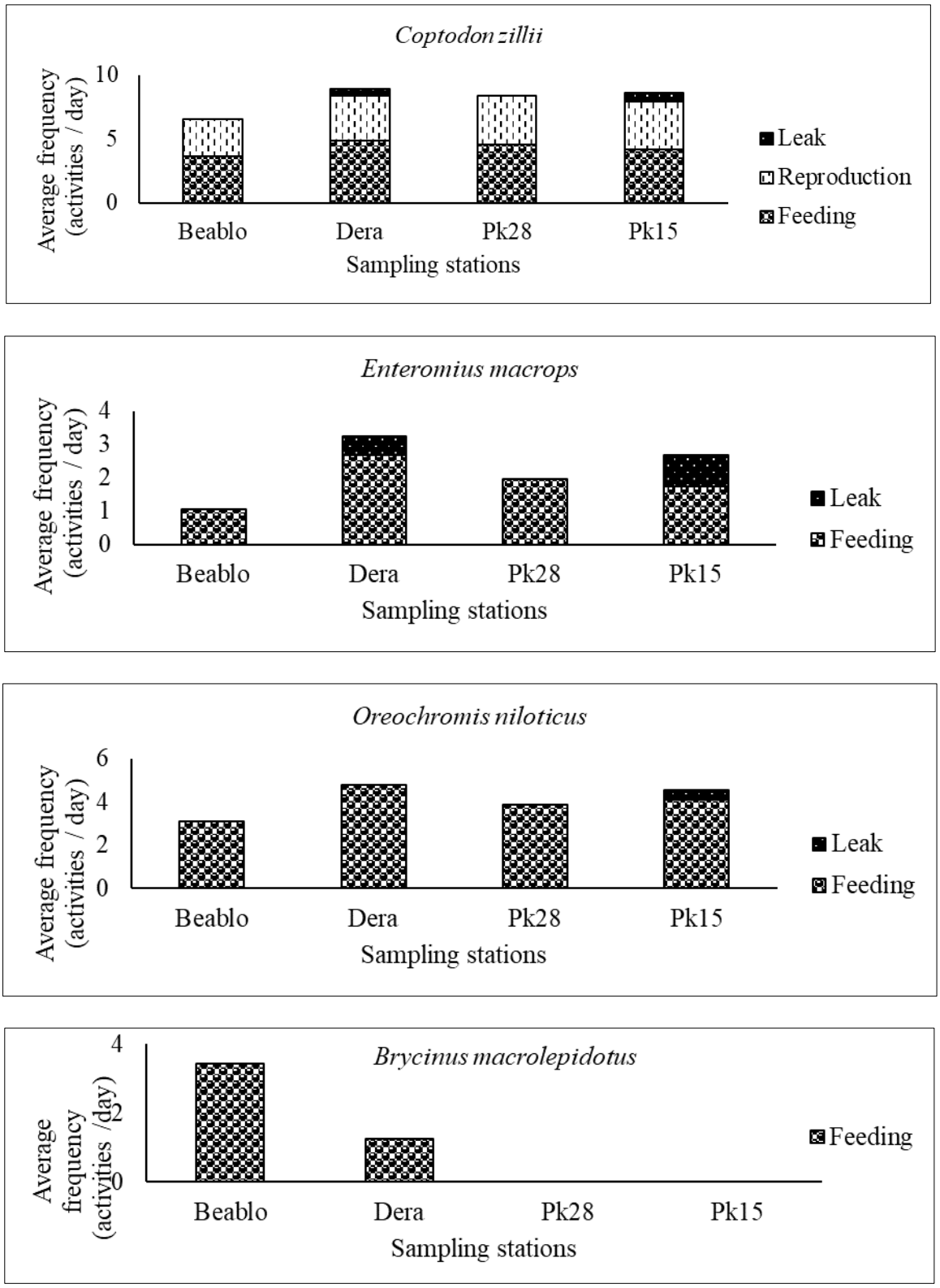


Figure 5 Spatiales variations in the average frequency of behavior types performed by species from January 2020 to December 2020.

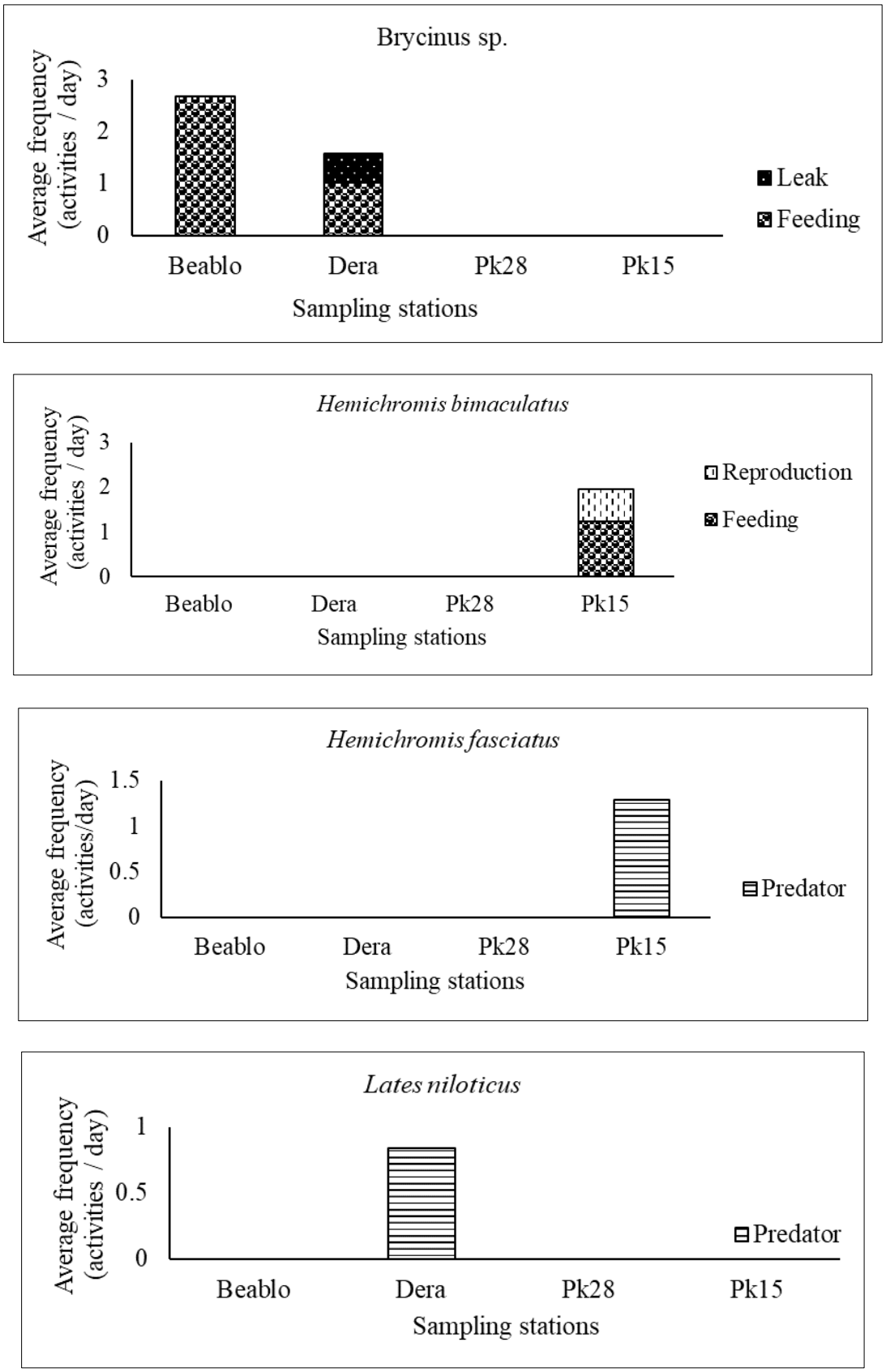


Figure 6 (continued) Spatial variation in the average frequency of behavior types performed by species from January2020 to December 2020.

3.4.3. Variation in the average frequency of observed behavior types by hydrological season

Variation in the mean frequency of behavior types performed by species according to hydrological season reveals that *Coptodon zillii* performs more activity during low-water periods than during high-water periods (Figure 7). The differences observed between seasons at all stations are not significant (Mann-Whitney test; $p > 0.05$). Of the behaviors performed by this species, feeding is the most common activity during high-water periods (63.41 to 79.56 %), while reproduction is the most common during low-water periods (48.33 to 73.91 %). Feeding and breeding activities by this species show significant seasonal variations at all stations (Mann-Whitney test; $p < 0.05$).

In the case of *Oreochromis niloticus*, the seasonal variation in the types of behavior performed by this species shows that it performs more activity during high-water periods and less activity during low-water seasons. The Mann-Whitney test indicates significant differences between periods at each station ($p < 0.05$). This species feeds virtually all year round at each station, with high mean frequency values during high water (90.12 to 100 %) (Figure 7). A significant variation was recorded in the mean frequencies obtained during high and low water seasons at all stations (Mann-Whitney test; $p < 0.05$). Escape behavior by this species was only observed during high-water seasons at station Pk15 (Figure 7). There was no significant difference between seasons (Mann-Whitney test; $p > 0.05$).

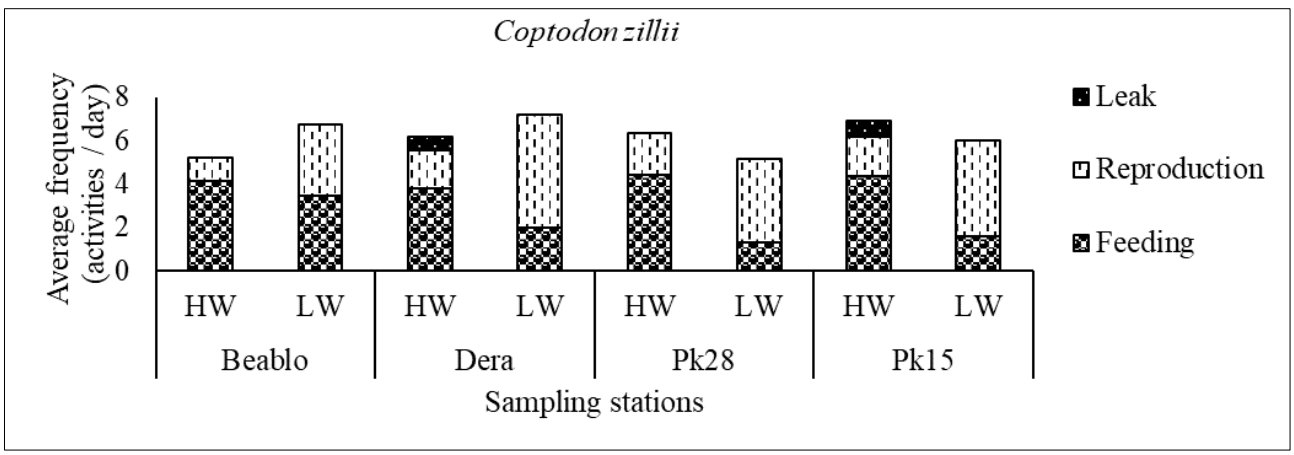
In *Enteromius macrops*, the mean frequency values for the types of behavior observed are higher in the high-water seasons than in the low-water period (Figure 7). The results of the statistical analysis indicate significant differences (Mann-Whitney test; $p < 0.05$) in the mean frequencies obtained between periods at each station. Of all the behaviors performed by this species, feeding is the most common, with high values during high-water seasons (66.33- 82.14 %). The differences observed are significant (Mann-Whitney test; $p < 0.05$). In contrast, leakage behavior was observed at stations Dera and Pk15 during high-water seasons (Figure 7). There are significant seasonal variations depending on the water level at Pk15 (Mann-Whitney test; $p < 0.05$).

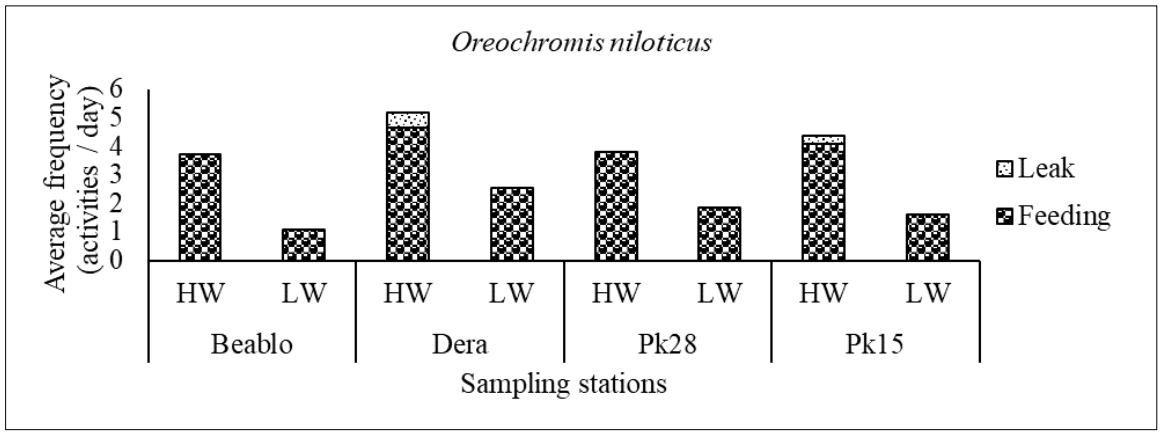
As for the *Brycinus macrolepidotus* species, the results show that the mean frequency of feeding behavior ishigher in the high-water season than in the low-water season at the Beablo and Dera stations (100 %) (Figure 7). However, there was no significant difference (Mann-Whitney test; $p > 0.05$) between the values of the mean frequency of feeding behavior performed by this species as a function of water level at each station.

Brycinus sp was more active during high water and less active during low water. Significant differences were observed (Mann-Whitney test; $p < 0.05$). Feeding is the most common activity carried out by this species, with higher mean frequency values in the high-water season than in the low-water season (82.60 -100 %) (Figure 8). Analysis of the results showed significant differences (Mann-Whitney test; $p < 0.05$) between periods.

Hemichromis bimaculatus show high mean frequency values during high-water periods (Figure 7). There was no significant difference between periods (Mann-Whitney test; $p > 0.05$). Feeding is most frequent during high-water season (100 %), whereas during low-water season, feeding is most frequent (100 %) (Figure 7). Significant seasonal variations were observed in the mean frequency of feeding and reproductive behaviors performed by this species (Mann-Whitney test; $p < 0.05$).

The species *Hemichromis fasciatus* and *Lates niloticus* recorded predation behaviour during high water at stations Pk15 and Dera respectively (Figure 7). Significant differences (Mann-Whitney test; $p < 0.05$) were observed between the mean frequency values recorded between seasons at stations Dera and Pk15.




Oreochromis niloticus
Average frequency (activities / day)
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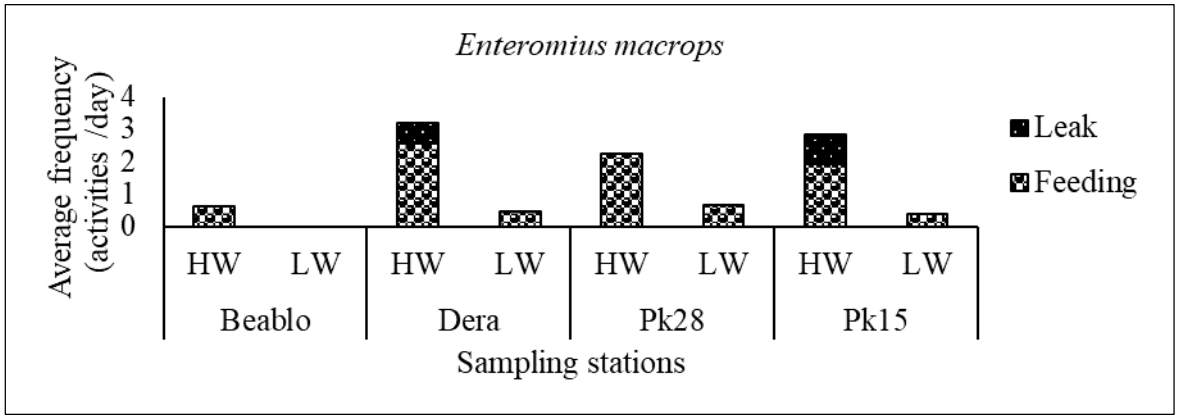
Pk28
Pk15
Sampling stations
Leak
Feeding


Enteromius macrops
Average frequency (activities /day)
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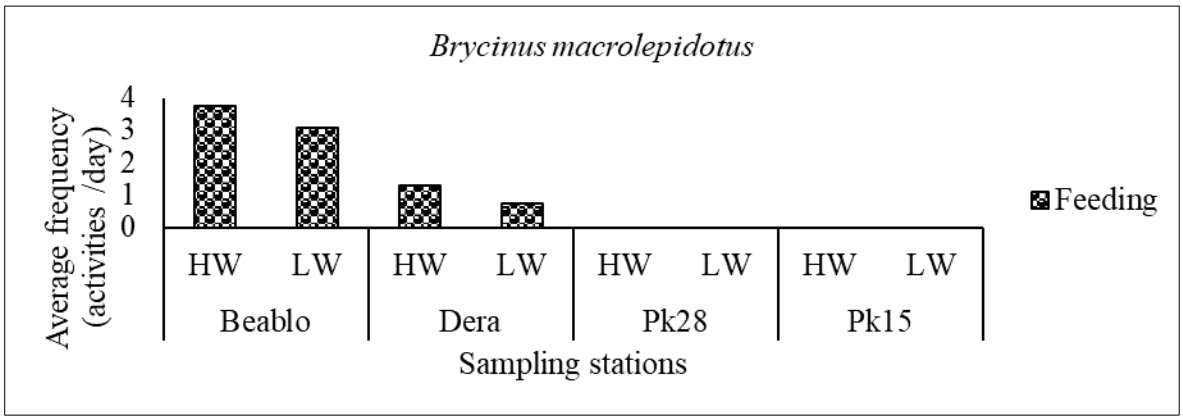
Brycinus macrolepidotus
Average frequency (activities /day)
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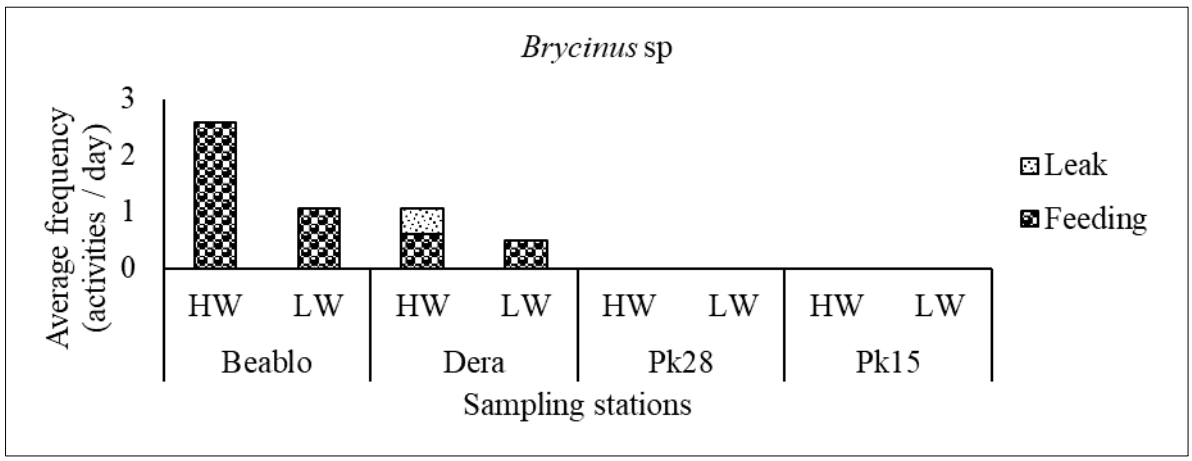
Sampling stations
Feeding


Brycinus sp
Average frequency (activities / day)
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Sampling stations
Leak
Feeding

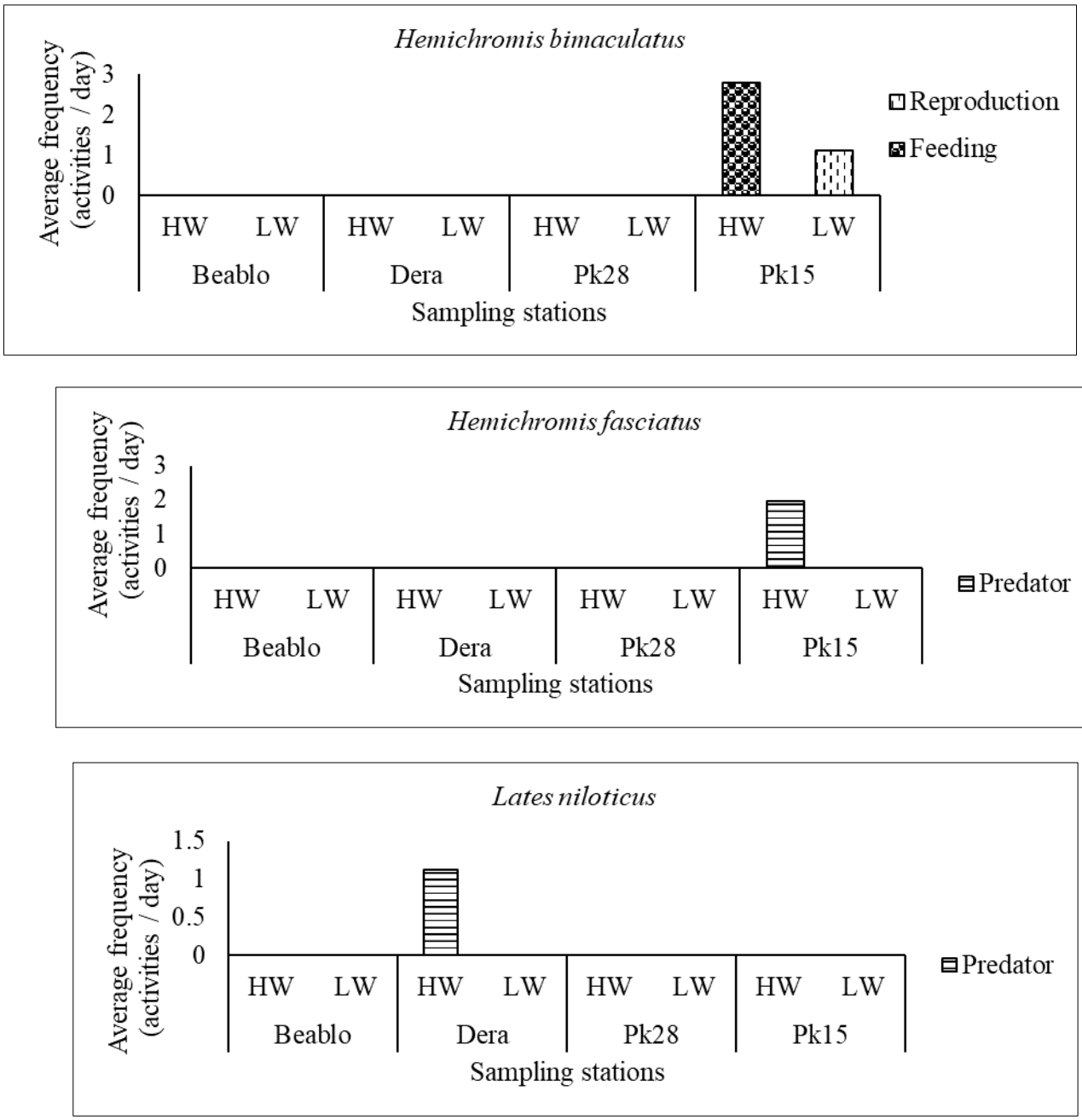

Figure 7 (continued) Variation in the average frequency of types of behavior performed by species as a function of the hydrological seasons from January to December 2020.

4. Discussion

The present study enabled us to observe eight species of fish using the littoral habitats of Lake Buyo to fulfill their requirements. This result could be attributed to the removal of bait on the observation devices deployed. Indeed, the addition of bait on underwater video surveillance devices produces an odor that attracts fish into the cameras' field of view, which favors the observation of several species [35, 36]. However, using cameras without bait allows natural observation of fish behavior in their environment [37]. Similar results were observed by Zarco-Perello & Enriquez [37] in Pueto Morelos National Park, located in the northernmost part of the Mesoamerican Barrier Reef. Video surveillance of littoral habitats enabled us to identify four types of behavior performed by the species observed in the field of view of the deployed cameras. The different behaviours performed by fish frequenting the littoral zones of Lake Buyo are: feeding, escape, predation and reproduction. These results are linked to the complexity and heterogeneity of Lake Buyo's littoral habitats, which offer fish the right conditions to fulfill their needs.

This study also shows that feeding behavior (62.70 %) is the most observed activity in the field of view of the deployed cameras. This could be explained by the fact that feeding is a behavior performed by all developmental stages of fish frequenting littoral habitats, whereas reproduction is performed by mature individuals [38, 39]. Moreover, this type of behavior provides the organism with the materials and energy it needs to carry out other behaviors, such as movement, reproduction, territory defense, etc. [2]. In addition, this dominance of feeding behaviour could be explained by the high availability of food resources such as insects, plankton, leaves, fruit, etc. in coastal areas, which are an important source of food for many fish species [40, 22, 15]. These observations are similar to those noted by Winfield [2] in the littoral zones of lake environments located in the United Kingdom and by Sheaves et al. [22] in a mangrove forest located in Australia.

The low proportion of escape (3.99%) and predation (0.99%) behaviours may be linked to the presence of few piscivores in the littoral habitats of Lake Buyo [41, 15]. On the other hand, the low values for predation and escape could be explained by the depth at which the recordings were made. According to numerous studies [42, 43-45], the risk of predation in aquatic habitats increases with depth.

The greater numbers of species and types of behaviour observed at stations Dera and Pk15 are probably linked to the natural configuration of these areas, with dense, tall seagrass beds that allow all the behaviours observed to be carried out. Hence the high presence of species in these habitats. In fact, compared with other types of habitat, these types of nearshore habitat provide more food resources [46, 47], stimulate fish spawning behavior [48] and offer better physical protection for the fish that frequent nearshore areas [49, 50, 51]. Consequently, behaviours aimed at modifying the vegetation cover of these areas will have a negative impact on the structure of the ichthyofauna, but also on the integrity of the water bodies.

Coptodon zillii was observed with the highest number of behaviour types and the highest mean frequency of activity in the present study. Such observations may be attributable to the high abundance of this species in the littoral habitats of Lake Buyo [41, 15] and the sedentarization of this species in shallow habitats [31, 15]. Indeed, the various habitats visited represent the preferred biotope of this species (i.e. an environment in which this species finds all the optimal conditions enabling it to fulfill its needs) [15].

The behaviours observed vary from one species to another. The results show that *Coptodon zillii* and *Hemichromis bimaculatus* feed more during high-water periods, whereas these species reproduce more during low-water periods. These results suggest that *Coptodon zillii* and *Hemichromis bimaculatus* adopt an adaptive behavioral strategy in response to particular environmental constraints, especially in this environment where environmental parameters vary greatly with water level fluctuations. Indeed, rising water levels supply littoral habitats with food resources by providing large quantities of nutrients through the production of phytoplankton, a source of food for many fish species [52]. However, when water levels drop, some major habitats (vegetated habitats) are lost and the majority of habitats that appear are composed of a substrate dominated by sand, which is suitable for nest building by these species. These results concur with those obtained by N'Dri [15] in the same environment. In addition, the work of Plourde-Lavoie & Sirois [53] showed that the littoral zone with a sand substrate represents the main breeding habitat for fish.

Like *Coptodon zillii* and *Hemichromis bimaculatus*, species such as : *Enteromius macrops*, *Coptodon zillii*, *Oreochromis niloticus*, *Brycinus macrolepidotus*, *Brycinus longipinnis* and *Brycinus* sp recorded high mean frequency values for feeding behavior during high-water periods. The use of these habitats as feeding sites by fish is linked to the high availability of resources at this time. In fact, during high-water periods, the water floods the macrophytes that have developed on the banks during low-water periods. This flooding provides littoral zones with a diversity of microhabitats and food resources for many fish during key phases of their life cycle [48], whereas the abrupt withdrawal of water leads to a loss of habitat and food. Similar results were obtained by Castillo-Rivera [54] in a Mexican estuary. This author recorded an increase in the rate of feeding activity during periods of high water, mainly due to the greater availability of food at this time. Rising water levels would make this food accessible to fish, which would explain the presence of these species in this environment. These results testify to the importance of the lake's littoral habitats and the need to protect them.

5. Conclusion

The recordings made in the present study showed that 08 fish species frequent the littoral habitats of Lake Buyo for feeding, shelter from predators and reproduction. Among these identified behaviors, feeding is the most observed in the field of view of the deployed cameras. The greatest numbers of species and types of behavior were observed at stations Dera and Pl15. Among the species observed, *Coptodon zillii* was the one with the highest number of behaviors and the highest average frequency of observed behavior types. In the course of this study, analysis of the video sequences showed that the behaviours observed varied from one species to another. The species *Coptodon zillii* and

Hemichromis bimaculatus feed more at high water and breed more at low water. In addition, all species feeding in this environment feed more during high water. The results of this study are particularly important for researchers, as the sampling method used enabled us to observe fish in their natural environment and to identify the types of behaviour performed by each species.

Compliance with ethical standards

Acknowledgements

This work is part of the project entitled "Evaluation of the diversity of the ichthyofauna of the coastal zone of the Buyo dam lake (South-West of Ivory Coast) through the use of Sports Cameras Waterproof". The authors would like to thank the Ivorian Office of Parks and Reserves (OIPR) and the Strategic Support Program for Research and Higher Education (PASRES) for their financial support.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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