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# Diet and Feeding Habits of *Bagrus bajad* (Fabricius, 1775, Bagridae) from Lake Albert, Nile Basin, Democratic Republic of Congo (DRC)

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## Abstract

The study of the diet of *Bagrus bajad* (Bagridae) was carried out on 520 specimens from the south-west of Lake Albert from December 2019 to December 2020. The relative importance index of food was used to evaluate quantitative aspect of diet. Percentages of global vacuity and average intestinal coefficient were 23.40% and 1.35, respectively. Analysis of 418 food-containing stomachs revealed that this fish has an omnivorous diet predominated by piscivorous and insectivorous. Larvae and juvenile fish of *Haplochromis spp* and *Oreochromis spp* and insects are the main foods. Molluscs, plant debris, plankton, etc. are accessory foods. Comparison between specimens of different sizes (TL 30.4 - 79.4 cm and SL 25.5 - 66 cm) showed no variation in diet. On other hand, a significant difference was noted in the food between sexes according to hydrological seasons. This difference reflects an abundance of food resources in rainy season which reduces food competition. Good fishing regulations should be established taking into account the seasons and the conservation of habitats that abound in the different types of food consumed by *B. bajad.*

**Subject Areas**

Aquaculture, Fisheries & Fish Science

**Keywords**

Bagridae, *Bagrus bajad*, Diet, Lake Albert, DR Congo

## 1. Introduction

In the Nile and its tributaries, the genus Bagrus of the family Bagridae includes two species, *Bagrus bayad* and *Bagrus docmac* forming a significant proportion of commercial catches in the fresh waters of the Nile basin [1]. In the water bodies of DR Congo, *B. bayad* is most common in Lake Albert while *B. docmac* is very rare in catches. On the other hand, B. *docmac* is the most caught in Lake Edward while *B. bayad* is absent. Fish of the Bagridae family are commonly known as naked catfish. They have four pairs of barbels with well-developed taste buds [2]. These 2 closely related species, *B. bayad* and *B. docmac*, have clear morphological differences: the two lobes of the caudal fin extend into long filaments in *B. bayad*, which is not the case for the upper lobe of *B. docmac* [3]. Alhassan and Ansu-Darko M [4] and Barley [4] stated that *B. bayad* is an omnivorous benthic (bottom-eater) fish due to the presence of detritus (bottom deposits) in addition to other foods inside the digestive tract. The food and feeding habits of *Bagrus* species have been reported by several researchers such as [5]-[10].

Examining the stomach contents of fish is very useful in guiding the formulation of artificial diets in fish farming. Fish exploit food substances in the aquatic ecosystem according to their morphological adaptations (mouth, gills, dentition and intestinal system) that are related to diet [11]. The objective of this study is the diet and feeding habits of *B. bayad* fish for the sustainable exploitation and management of the fishery for this species in Lake Albert.

## 2. Materials and Methods

### 2.1. Study Environment

Lake Albert (**Figure 1**), formerly known as Lake Mobutu Sese Seko, is shared between Uganda (54%) and DRC (46%). It is the northernmost of the chain of lakes of the western arm of the Great Rift Valley in Africa at coordinates 100'N 3005'E. Compared to most other African Great Lakes (AGLs), Lake Albert is relatively shallow and relatively small, with an average depth of 25 meters and an area of 5300 km$^2$.

Its outlet at the northern end is the Albert Nile, also known as the White Nile, which joins the Blue Nile in South Sudan to form the famous Nile that flows through Egypt and empties into the Mediterranean Sea. Temperatures range from 17˚C to 29˚C [12].

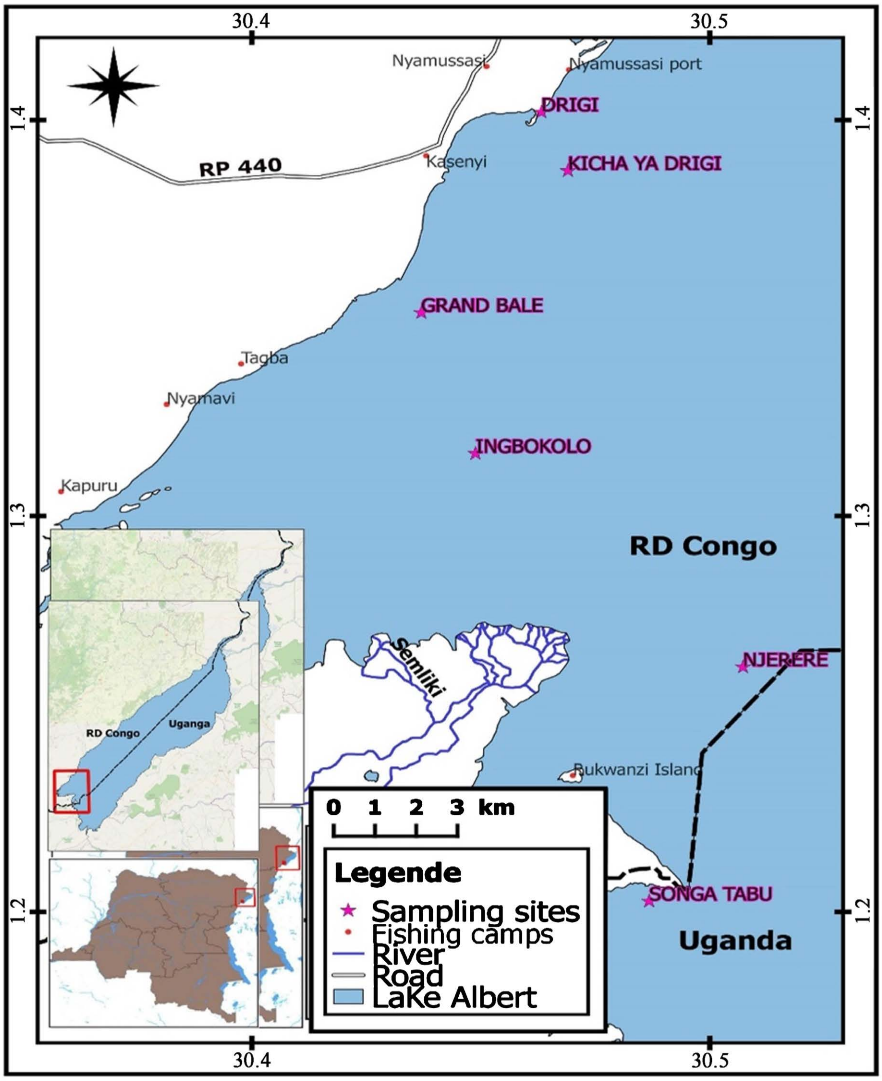


Figure 1. *B. bayad* sampling sites (•) at Lake Albert DRC.

## 2.2. Sampling and Dissection of Fish

Fish were caught monthly from December 2019 to December 2020 using various fishing gear, including longlines, hawks and gillnets of different standard mesh sizes (20.2, 25.4 and 30.5 mm) and canoes were used as fishing boats.

These nets were laid around 5 p.m. and collected the next day at 7 a.m. for night fishing, then surveyed at 12 p.m. for daytime fishing. Fish caught were identified according to [13]. Each specimen was weighed and measured (standard length and total length) to the nearest gram and millimeter respectively. After dissection, the stomach was removed and stored in 5% formaldehyde.

## 2.3. Analysis of Stomach Contents

The main difficulty in analyzing stomach contents is the condition of prey. They are often dislocated or even partially digested making identification tedious. In the laboratory, after incision, the stomach was weighed and emptied of its contents. The stomach contents were diluted in a petri dish containing water. The different food taxa were sorted and counted under a BINOCULAR MAGNIFYING GLASS OF THE BRAND LEICA WILD HEERBRUGG Mg with magnification x 6 to 50. Next, these foods were weighed using a SARTORIUS UNIVERSAL brand scale to the nearest 0.01 g and examined individually. The different preys were identified down to the family from the determination keys of [14] [15]. Other keys established for French and English faunas have also been consulted, including: [16] [17] [18]. Prey whose state of digestion did not allow the exact identification of these were considered debris. The relative abundance of each prey was estimated using seven (7) indices:

1) Percentage of numerical abundance (Cn) = the number of each prey in all non-empty stomachs relative to the total number of all foods;

2) Percentage of occurrences (%$O$) [19]:

$$\%O = \left( N_{ei} / N_{and} \right) \times 100 \tag{1}$$

where $N_{ei}$ is the number of stomachs containing an item $i$ and $N_{and}$ the number of non-empty stomachs examined;

3) Numerical Percentage (%$N_i$) [20]:

$$\%N_i = \left( N_i / N_t \right) \times 100 \tag{2}$$

where $N_i$ and $N_t$ are respectively the number of individuals in a category of prey $i$ and the total number of individuals of the prey inventoried;

4) Percentage by weight (%$P_i$) [21]

$$\%P_i = \left( M_i / M_t \right) \times 100 \tag{3}$$

with $M_i$ the mass of a prey category $i$ and $M_t$ the total mass of All items listed;

5) Relative Food Importance Index (ARI) [22]

$$\text{IRA} = \left[ \left( \%O + \%N + \%P \right) / \sum \left( \%O + \%N + \%P \right) \right] \times 100 \tag{4}$$

$$\text{Va value index} \left( \text{IV} \right) = \left( \text{NEV} / N \right) \times 100 \quad [23] \tag{5}$$

where NEV is the number of empty stomachs and $N$ is the total number of stomachs examined;

$$\begin{aligned} &\text{Satiety index} \left( \text{SI} \right) \\ &= \left( \text{Number of empty stomachs} / \text{Total number of stomachs} \right) \times 100. \end{aligned} \tag{6}$$

The different items were classified according to Georges and Hadley's scale [24] which establishes that prey is primary if ARI > 50%; secondary if IRA is between 10% and 50% *and incidental or accidental if IRA* $< 10\%$.

## 2.4. Statistical Analysis of Data

The Spearman rank correlation test was performed to compare diets based on size, sex, and hydrological seasons. Statistical analyses were performed using STATISTICA version 14 software and similarities were considered significant at $p = 0.05$.

# 3. Results

## 3.1. Intestinal Coefficient and Coefficient of Emptiness

A total of 520 fish were examined. Of these, 22 fish were empty, a percentage of emptiness of 4.23%.

The intestinal coefficient of *B. bayad* caught in Lake Albert ranges from 0.85 to 2.5 with an average of 1.35 > 0.48.

## 3.2. General Diet Profile

Table 1 presents the qualitative and quantitative aspects of the diet of *B. bayad*.

Table 1. Qualitative and quantitative diet composition of *B. bayad* caught in Lake Albert in 2020 (%*N* = numerical percentage, %*O* = percentage of occurrence, RIF = relative importance of food).

| Item | %*N* | %*Oc* | RIF |
|---|---|---|---|
| ***Fish*** | **35.89** | **90.96** | **35.89** |
| Oreochromis spp. | 11.71 | 37.15 | 11.71 |
| Haplochromis spp. | 23.29 | 73.90 | 23.29 |
| Fish remains | 0.89 | 2.81 | 0.89 |
| ***Insects*** | **32.97** | **67.07** | **32.97** |
| Remains of insects | 16.77 | 53.21 | 16.77 |
| Odonate | 13.67 | 43.37 | 13.67 |
| Cladocerans | 2.53 | 8.03 | 2.53 |
| ***Molluscs*** | **11.39** | **36.14** | **11.39** |
| Molluscs | 11.39 | 36.14 | 11.39 |
| ***Crustaceans*** | **2.41** | **5.62** | **2.41** |
| Crabs | 0.89 | 2.81 | 0.89 |
| Shrimp/shrimp | 1.52 | 4.82 | 1.52 |
| ***Sands*** | **0.25** | 0.80 | 0.25 |
| Sands | 0.25 | 0.80 | 0.25 |
| ***Plankton*** | **5.25** | **8.63** | **5.25** |
| Phytoplankton | 2.72 | 8.63 | 2.72 |
| Zooplankton | 2.53 | 8.03 | 2.53 |
| ***Plant debris*** | **11.84** | 37.55 | 11.84 |
| Plant debris | 11.84 | 37.55 | 11.84 |
| Pisces | 35.89 | 90.96 | 35.89 |
| Insects | 32.97 | 67.07 | 32.97 |
| Molluscs | 11.39 | 36.14 | 11.39 |
| Crustaceans | 2.41 | 5.62 | 2.41 |
| Sands | 0.25 | 0.80 | 0.25 |
| Plankton | 5.25 | 8.63 | 5.25 |
| Plant debris | 11.84 | 37.55 | 11.84 |

The analysis of stomach contents made it possible to distinguish six (6) categories of prey namely fish, insects, mollusks, crustaceans, plankton and plant debris and sand. In addition to these preys, there is a significant proportion of unidentified prey remains that have not been considered as an item.

Fish were the most numerous followed by insects and constitute respectively 35.89% and 32.97% of the prey inventoried. Fish appear in 90.96% of the stomachs assessed while insects were found in 67.07% stomachs. Plant debris comes in third place with an occurrence percentage of 11.84%. Plankton and crustaceans have a numerical percentage of 5.25% and 2.41% respectively.

The integration of these different percentages reveals that fish and insects together constitute the primary prey, mollusks and plant debris represent the secondary prey while plankton, crustaceans and possibly sand constitute accidental prey.

### 3.3. Study of Diet According to Sex of Individuals

The study of diet of *B. bayad* by sex identified six (6) items and showed that fish and insects remain the main prey regardless of sex (Table 2). Plant debris (macrophytes) and plankton were much greater in males while mollusks were more important in females. Sand was found only in the stomachs of females. Males and females would exploit different niches during certain periods of the year (seasons). Females appear to be more bentic (mollusks and sands) than males. The relative importance index reveals that fish and insects are primary prey with 35.92% and 31.20% for males and 35.87% and 34.04% for females respectively.

The Spearman correlation coefficient calculated from the materiality index indicates that the diets of males and females are not significantly different (N = 7, R = 0.89, $p = 0.0068$).

### 3.4. Study of Diet According to the Size of Individuals

Figure 2 shows the results of the analysis of stomach contents as a function of fish size. It can be seen that for class I (LT ≤ 45 cm), seven (7) categories of prey were represented while in class II (LT > 45 cm) only five categories were recorded. Crustaceans and sand were not found in Class II.

In terms of the materiality index, fish and insects together constituted the primary prey in class I (the most consumed), with respectively an IRA of 35.87%, 34; 04.70% respectively; while class II has as secondary prey molluscs (IRA = 13.18%) and plant debris (ARI = 10.33%). Crustaceans, plankton and sands come in the last class with respectively (IRA = 3.24%; 2.63% and 0.41). It is noted that for class I fish were the most preferred while in class II insects were the most preferred. The Spearman test (N = 7, R = 0.72, $p = 0.0676 > 0.05$) revealed a statistically insignificant difference between the diets of *Bagrus bayad* of total length less than or equal to forty-five centimeters and those of sizes greater than forty-five centimeters.

### 3.5. Study of the Diet According to Hydrological Seasons

The results of the stomach contents analysis according to hydrological seasons

**Table 2.** Diet *B. bayad* by sex of individuals from Lake Albert (%*N* = numerical percentage, %*Oc* = percentage of occurrence, AKI = relative importance of the food).

| Item | Male | | | Female | | |
|---|---|---|---|---|---|---|
| | *%N* | *%Oc* | *Ira* | *%N* | *%oc* | *Ira* |
| ***Fish*** | | | | | | |
| Tilapia spp. | 12.31 | 36.32 | 12.31 | 11.35 | 37.71 | 11.35 |
| Haploch. Spp. | 23.27 | 68.66 | 23.27 | 23.30 | 77.44 | 23.30 |
| Fish remains | 0.34 | 1.00 | 0.34 | 1.22 | 4.04 | 1.22 |
| ***Insects*** | | | | | | |
| Remains of insects | 15.35 | 45.27 | 15.35 | 17.63 | 58.59 | 17.63 |
| Odonate | 11.80 | 34.83 | 11.80 | 14.79 | 49.16 | 14.79 |
| Cladocerans | 4.05 | 11.94 | 4.05 | 1.62 | 5.39 | 1.62 |
| ***Molluscs*** | | | | | | |
| Molluscs | 7.93 | 23.38 | 7.93 | 13.48 | 44.78 | 13.48 |
| ***Crustaceans*** | | | | | | |
| Crabs | 1.18 | 3.48 | 1.18 | 0.71 | 2.36 | 0.71 |
| Shrimp | 0.85 | 2.49 | 0.85 | 1.93 | 6.40 | 1.93 |
| ***Sands*** | | | | | | |
| Sands | - | - | - | 0.41 | 1.35 | 0.41 |
| ***Plankton*** | | | | | | |
| Phytoplankton | 4.55 | 13.43 | 4.55 | 1.62 | 5.39 | 1.62 |
| Zooplankton | 4.05 | 11.94 | 4.05 | 1.62 | 5.39 | 1.62 |
| ***Vegetal debris.*** | | | | | | |
| Vegetative debris. | 14.33 | 42.29 | 14.33 | 10.33 | 34.34 | 10.33 |
| *Pisces* | 35.92 | 87.56 | 35.92 | 35.87 | 93.27 | 35.87 |
| *Insects* | 15.85 | 65.17 | 31.20 | 34.04 | 68.35 | 34.04 |
| *Molluscs* | 7.93 | 23.38 | 7.93 | 13.48 | 44.78 | 13.48 |
| *Crustaceans* | 1.52 | 4.48 | 2.02 | 2.63 | 6.40 | 2.63 |
| *Sands* | - | - | - | 0.41 | 1.35 | 0.41 |
| *Plankton* | 4.55 | 13.43 | 8.60 | 3.24 | 5.39 | 3.24 |
| *Plant debris* | 14.33 | 42.29 | 14.33 | 10.33 | 34.34 | 10.33 |

(**Figure 3**) reveal seven (7) categories of prey including fish, insects, molluscs, crustaceans, plankton, plant debris and sand in each of the two seasons (dry and rainy).

The study of the relative importance index shows that fish (IRI S. rain = 36.61%, IRI S. dry = 34.94%), insects (IRI S. rain = 32.81%, IRI S dry = 33.19%), plant debris (IRI S. rain = 11.94%, IRI S. dry = 11.70%) and molluscs (IRI S. rain

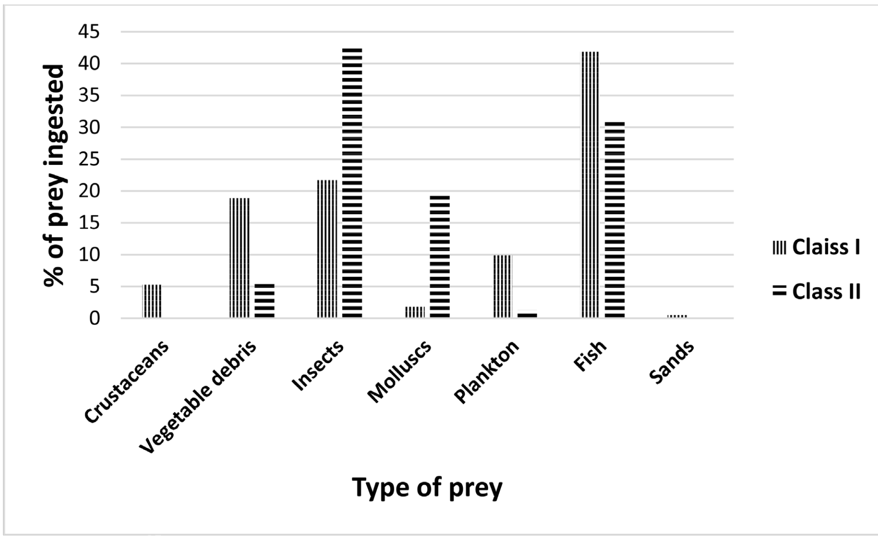


**Figure 2.** Diet of *B. bayad* from Lake Albert as according to total length of individuals (ARI: Relative Importance of Food, Class I: LT ≤ 45 cm, Class II: LT > 45 cm).

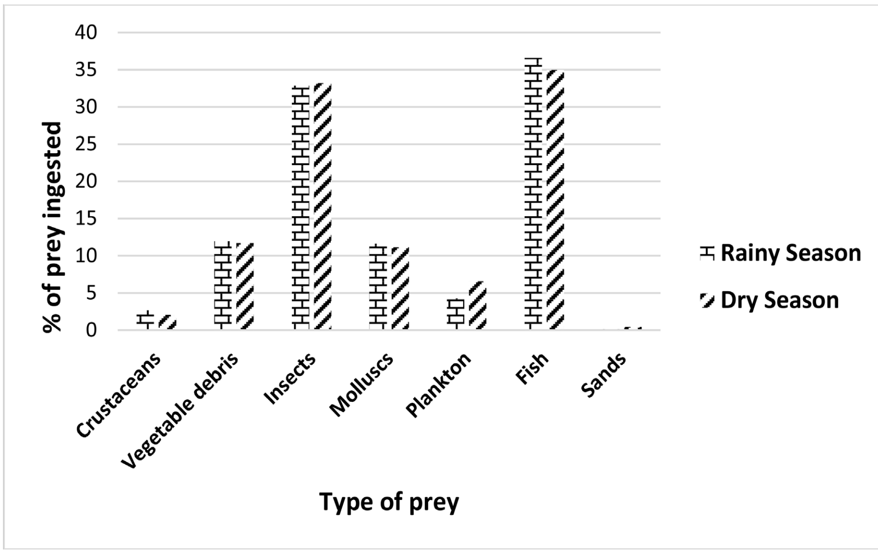


**Figure 3.** Comparative diet analysis according to hydrological seasons of *B. bayad* captured in Lake Albert in 2020 (ARI = Relative Importance of Food, SP = rainy season, SS = dry season).

= 11.61%, IRI S. dry = 11.11%) are secondary prey in both seasons while plankton have been accidental prey.

Comparative analysis of diet according to hydrological seasons revealed a significant difference between the rainy and dry seasons (N = 7, R = 1.00, $p = 0.00$).

## 4. Discussion

The present study reveals that *B. bayad* fed on fish mainly juveniles and larvae of *Haplochromis spp* and *Oreochromis spp*. followed by juvenile and adult insects in particular Odonates and Ephemeroptera, which together constituted the primary prey of its diet. The secondary diet consisted of molluscs and phytobenthic detritus while the incidental or accidental diet consisted of plankton, freshwater shrimp, crustaceans, and sand and other unidentified materials.

Thus, according to the relative importance index, *Bagrus bayad* is therefore omnivorous mainly piscivorous and then insectivorous. These results agree with those of [25] [26] who found that Bagridae, especially *B. bayad*, rely primarily on fish, insects and shrimp as well as fish larvae for food and that their stomachs included runoff materials (plant foliage, glass, black crystals, colored gravel) in the Nilotic Bahr Shebeen Channel. Nevertheless, other authors have observed that it is polyphagous, feeding on fish and invertebrates or sometimes only invertebrates. Sandon and Latif [27], report that *B. bayad and B. docmac* are carnivorous, feeding mainly on fish (*Tilapia*, *Alestes*, *Synondotis*, *Mormyrus*, *Labeo*, *Barbus*, *Eutropius* spp.), insect larvae, molluscs and water shrimp. Bailey & Alhassan [28] and Alhassan and Ansu-Darko [3], on the other hand, declared that *B. bayad* is an omnivorous benthic (bottom eater) due to the presence of detritus (bottom deposit) in addition to other foods inside the digestive tract.

The present work also revealed the presence of plant and animal detritus in the stomachs of *B. bayad*. This is consistent with the findings of Bailey [4], El-Drawany *et al.* [9], who showed that the presence of detritus in addition to other foods such as zooplankton, fish, insects, phytoplankton as well as insect parts. Khallaf and Authman [19] reported that the presence of mud or sand and various strange materials in some of the examined stomachs of *B. bayad* suggests a bottom diet, whereas *B. docmac* depends mainly on fish and insects for food [3]. Similarly, in addition to fish, insects and other elements, the present study found that *B. bayad* also feeds on mud, sand and other elements suggesting bottom feeding.

Other previous studies on the feeding habits of *B. docmac* and *B. bayad* in the Inhibiting Muess Channel (Egypt) have clarified that *B. docmac* is carnivorous andhave noted that *B. bayad* is an omnivorous benthic [3] [9] [24]. The present results confirm the last author.

In addition, Jean Veberke [10] and Greenwood [14] having investigated the diet of the genus *Bagrus* in Lake Victoria, had respectively confirmed that the stomach contents of these species were regularly made up of small fish (fry and young), the majority of which were *Haplochromis spp*. They had also added insect larvae especially Chironomidae; and finally, the taking or not of plant substrate or silt. Compared to these two authors, the other three types of foods mentioned above could be an innovation for this study. According to these authors, the incidental content consisted of various invertebrates (insect larvae: Ephemeroptera, Chironomidae and *Chaoborus*). This led them to conclude that the diet of the genus *Bagrus* spp was voracious and occasionally entomophagous (Odonates). The results of the current investigation, on the other hand, have confirmed that the diet of *Bagrus bayad* is omnivorous or polyphagous predominantly piscivorous-insectivorous. The present study does not also agree with the thesis of Alsafy *et al.* [8], who, from the crude and microscopic scanning electron morphology of the oropharyngeal cavity of *Bagrus bayad*, had concluded that the diet of this fish is carnivorous because of the high number of sharp teeth and other dental and oral characteristics (group of taste buds, form and organization of microridges). Unlike these authors, the present study demonstrated the predominantly piscivorous and insectivorous polyphagous diet. Verbeke [14], had also concluded that the diet of the *Bagrus bayad* of Lake Albert was Entomo-Benthophagus, with dominance of larvae of *Povilla*, Chironomidae, shrimps, algae and plants while various invertebrates constitute the incidental contents (Trichoptera, Odonates, Corixidae, Ostracodes,) associated with fry and young fish, molluscs and mud. Greenwood [14] had also found the same type of diet at Lake Victoria for the same species. After six decades the present results have rather proved that the diet of this species of fish is polyphagous (voracious) preferably piscivorous-insectivorous (dominant food) possibly associating various food resources as accidental prey.

The monthly change in stomach fullness index indicates a change in the dietary activity of *B. bayad.* However, among the 520 stomachs of the specimens studied, 22 stomachs were found empty, a percentage of emptiness of 4.23%. The Spearman correlation coefficient calculated from the materiality index indicates that the diets of males and females are not significantly different ($N = 7$, $R = 0.89$, $p = 0.0068$). The results of stomach contents as a function of the size of the fish grouped by classes, note the preference for fish in Class I (TL < 45 cm) and for insects in Class II (TL > 54 cm). This corresponds to the Okito *et al.* [28]; Castillo-Rivera results [6]; Konan *et al.* [20] who had observed these food preferences resulting from the effects of runoff, carrying significant quantities of invertebrates, in this case terrestrial insects that enrich waterways during this period. This clearly contributes to the high proportion of insects in stomach contents during the rainy season.

The Spearman test ($N = 7$, $R = 0.72$, $p = 0.0676 > 0.05$) revealed a statistically significant difference between the diets of *B. bayad* whose total size is ≤45 cm to those of sizes ≥ 45 cm.

The study of feeding behavior as a function of size, revealed that fish are the preferred food of individuals regardless of size, which corresponds to the results of Forskal [12] [27] [28] [29], Greenwood [14], Castillo-Rivera [6] and Konan *et al.* [1]; according to Gophen [27], variation in diet in a given species may be related to the level of differentiation of the digestive tract and the habitat exploited. However, they confirmed that fish of different size classes (LS ≤ 110 mm and >110 mm) were all caught in the same biotopes.

Comparative analysis of diet by hydrological seasons revealed a significant difference between the rainy and dry seasons ($N = 7$, $R = 1.00$, $p = 0.00$). This difference reflects an abundance of food resources during the rainy season that reduces food competition in that season. This was found by Castillo-Rivera (2013) and Konan *et al.* [1], concluding that stomach contents were more loaded with insects during the rainy season than during the dry season, hence the entomophagous diet proclaimed for Bagrus. Similarly, Khallaf and Authman [19] found that winter was characterized by lower dietary element values than summer for this fish species. He explained this phenomenon by the low availability of various items in winters caused by a drop in temperature and a shorter duration of daylight. Our study found a certain abundance of fish in stomach contents, indicating that the species *Bagrus bayad* is more piscivorous than insectivorous.

## 5. Conclusions

This study aims to provide *B. bayad* for sustainable management of this species and feeding strategies of *B. bajad* for sustainable management of this species in the Congolese part of Lake Albert. The species has opportunistic feeding behaviour and explores different habitats in the lake: the littoral zone, the surface of the water body and the muddy bottom. She has the ability to adapt her diet according to the resources available in the environment and according to the seasons. As a result, the food spectrum of this species is relatively wide. Fish predominate in the diet of *B. bayad* and are followed by insects. No significant changes were noted in diet depending on the size of the fish. On the other hand, hydrological seasons and sexes influence diet. The study also confirms Verbeke's remark [4], that in this Lake Albert with a more varied and richer fauna than in Lakes Edward and Kivu, the diet of many fish was also more diverse. Therefore, it became more difficult to specify a dominance in their diet, which tended to become polyphagous in a number of species, including: *Auchenoglanis occidentalis*, *Distichodus niloticus*, *Synondontis schall*, *Clarias lazera*, Bagrus docmac, etc. is different in Bagrus bajad. The entomophagous diet observed by Vebeke in 1959 in other fish families *such as Mormyridae*, *Characidae*, *Cyprinidae*, *Clariidae*, *Bagridae*, *Schilbeidae and Cichlidae of the genus Haplochromis* is different in *Bagrus bajad as confirmed by this study.* After more than half a century, the observed variations in the diet of this species are possible and obvious.

The effects of climate change observed in the region for decades on the one hand, and local anthropogenic actions on the other (destruction of habitats and spawning areas by illegal fishing, use of land for agriculture and livestock, urban agglomerations and the development of fishing villages in the coastal zone) on the lake ecosystem and even in the entire catchment area of this lake have immediate direct effects. These anthropogenic actions destructive of the ecosystem would have contributed to the scarcity, probably the disappearance of certain species of invertebrates, macro-invertebrates, phytobenthos, which once constituted the main groupings of the food resources of the fish of this lake (benthic, pelagic and coastal). Given the importance of sustainable management of fisheries resources, diet studies should be extended to other commercial fish species in order to provide the scientific information necessary for their management. On the other hand, good regulation of fishing should be established taking into account the seasons and the conservation of habitats on which the different types of food consumed by *B. bayad* depend.

## Authors' Contributions

JMM was involved in all phases of the study. These include study design, data collection, tabulation, data processing and analysis, and writing of this manuscript; GMO was involved in study design, tabulation, data processing and analysis, and writing of this manuscript. KK, JJ was involved in the collection, counting, processing and analysis of the data. MM, VMN, JCM, GN and SIL contributed to the correction of the manuscript.

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## Conflicts of Interest

The authors declare no conflicts of interest.

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