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Variation in the diet of *Labeobarbus altianalis* Boulenger, 1900 (Cypriniformes, Cyprinidae) from Lake Edward, DR Congo: Depending on the size of the individuals

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Abstract
The fieldwork for the present paper was carried out during three months, from July to September 2011, with a view to carrying out a study on the variation in diet according to the sizes of *Labeobarbus altianalis*, Cyprinidae of Lake Edward. Fish were collected using 7.5cm mesh gillnets, 5cm mesh beach seines, fiknet fishing, line fishing with hooks using appropriate bait and baskets. The analysis of stomach contents allowed us to conclude that the diet of *Labeobarbus altianalis* of small size (10 to 31 cm) is essentially composed of insects while that of *Labeobarbus altianalis* of larger size (32 to 77 cm) is made up of fish. Plant debris is consumed by both small and large *Labeobarbus altianalis*.

Keywords: Total length feeds, stomach contents, food indexes, dietary indexes, plant debris, phytoplankton, zooplankton, insects

1. Introduction
Lake Edward is one of the great lakes of Africa located in the northeast of the Democratic Republic of the Congo, bordering Uganda. The first European to discover it was Henry Morton Stanley in 1888. He named it in honor of Edward Prince of Wales. The lake was later named Lake Idi Amin or Lake Idi Amin Dada after the Ugandan dictator Idi Amine Dada. The lake reverted to its name from Lake Edward not long ago. Its other names are: Albert-Edward and Louta N'zighe (Lebrun 1938) [1].
It seems that the distribution of organisms in Lakes Edward, Kivu and Victoria has traits with geomorphological and historical facts. Before the eruption of the Virunga volcanoes, Lake Kivu was part of a hydrographical system flowing north into Lake Edward. The volcanic eruption blocked the flow towards the north and the waters invaded the Albertine Rift valley to form today's Lake Kivu. The level then rose until it forced an exit towards the South towards Lake Tanganyika (Gréboval, 1991) [2]. Although Lake Kivu is no longer attached to Lake Edward, the fish composition of the two lakes is quite similar. On the other hand, the fauna of Lake Kivu is not related to that of Lake Tanganyika with which it has recently been linked and which presents greater fish diversity (Beadle 1981) [3]. Apart from some works such as those of Mbalassa *et al.*, (2008) [4] which provides information on the distribution of certain species of fish in Lake Edward as well as Lauzanne (1976) [5] who gave the diet of the *Labeobarbus* genus, we do not find any information updates on the reproduction and diet of *Labeobarbus altianalis* in this lake. And yet, according to Maes (1991) [6], it is among the fish which are truly the subject of commercial exploitation and its conservation status by the International Union for Conservation of Nature (IUCN, 1990) [7] shows that this species is listed on the red list. It should also be noted, according to the report of the second technical consultation on the fishery development of Lakes Edouard and Mobutu, that at present, one of the lakes, Lake Edouard, was already overexploited and that the sustainability of its resource was called into question.

However, it remains to be remembered that fishing is a main activity for local populations (Lebrun 1938) [1].
In this context, the study aimed to document the study of the variation in the diet of *Labeobarbus altianalis* according to size variation at Lake Edward for fish and biodiversity conservation in Lake Edward. Knowledge of the diet of a fish of capital importance because it allows us to understand the types of relationships that the latter maintains with other ichthyological species in the aquatic ecosystem (Joseph, 2015) [8]. This species has also been described by many scientists, notably (Poll, 1935) [9]. *Labeobarbus altianalis* inhabits the coasts of streams and rivers. It prefers the substrate to sand and gravel. Its fry remain on coastal river habitats; adults inhabit the coasts of rivers and lakes. Gastropods and molluscs are important nutrients in the lake while insects and larvae are equally important in very deep areas. Furthermore, it should be noted that plants, fish and crustaceans are also consumed by *Labeobarbus altianalis*, but a lot of plant material is consumed by its fry. Oviparous, *Labeobarbus altianalis* is a fish preferred for human food (Lebrun 1938) [1].
Knowledge of the diet of a fish is of capital importance because it allows us to understand the types of relationships that the latter maintains with other ichthyological species in the aquatic ecosystem (Joseph, 2015) [8]. In this context, we wanted to make our contribution to the study of the variation in the diet of *Labeoarbus altianalis* according to size at Lake Edward.

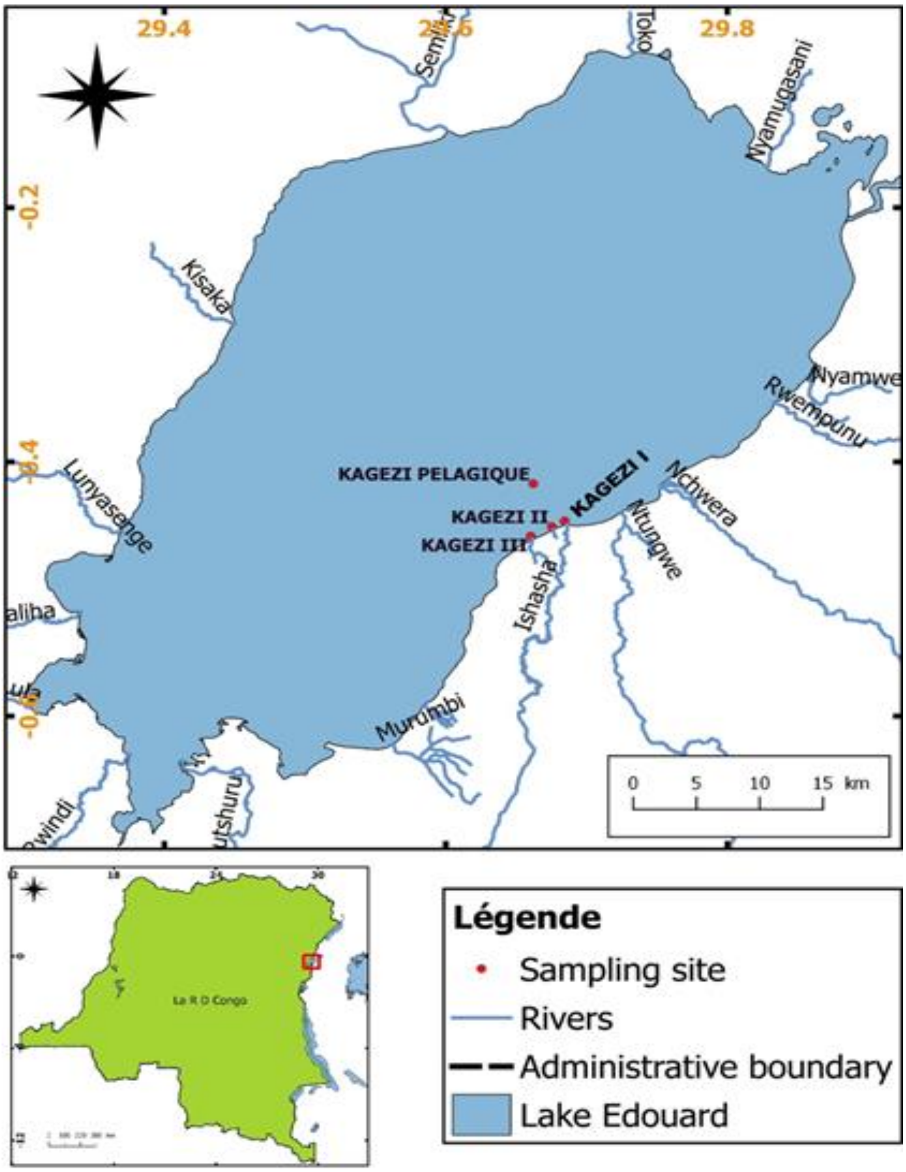

Fig 1: Localization of sampling sites on Lake Eduard on the Congolese side

2. Materials and Methods

2.1 Description of study area

Lake Edward is located in East Africa between 0° 4' and 0° 39' South latitude and 29° 30' and 30° 5' East longitude, in the western part of the Albertine Rift valley (Georges, 1991) [12]. The lake borders Uganda (29% of its surface) and the Democratic Republic of Congo (71% of its surface). Lake Edward is attached to Lake Georges by the Kazinga Canal, which explains why several species of fish are common to both lakes (Georges, 1991) [10]. It is essential to consider Lake Edward in its geographical context: It is surrounded by two national parks, the Queen Elizabeth National Park (QENP) in Uganda and the Virunga National Park (PNVi) in the Democratic Republic of the Congo. The Muhinga Forest (gorilla reserve) and the Chamburi Game Park are also close to this lake. These protected areas extend over nearly 380 km from North to South. The waters of Lake Edward and the Kazinga Canal are included entirely within the limits of this protected region (Georges, 1991) [12]. Lake Edward has an average depth of 33 m but this is unevenly distributed. In Ugandan waters, the average depth is 17 m and never exceeds 40 m deep. On the other hand, on the Congolese side, the lake is deeper: Its average depth is 40 m and the maximum depth is 117 m; it is only reached 5 km from the coast which, at this location, rises suddenly towards the relief exceeding 2500 m altitude. These deeper waters are less productive than in the Ugandan part where the slope is much gentler (René and Daniel, 1991) [11]. The lake is fed mainly by the Nyamusanze River, in the north which drains a south-western part of the Ruwenzori Mountains, and in the south, the Ishasha, Rutshuru and Rwindi rivers. It also receives the Kazinga canal, which connects it to Lake George located in Ugandan territory, but the contribution of the latter to the waters of the lake is low compared to that of the rivers. Its outlet is the Semuliki River, which flows northern into Lake Mobutu (René and Daniel, 1991) [13]. Sampling was carried out in Lake Edward located in the territory of Rutshuru, North Kivu Province in the Democratic Republic of the Congo. Data collection was done first in the coastal areas (Kagezi I, Kagezi II and Kagezi III) at a depth between 0 and 2 m (distance from the coast of 0-200 m) as well as in pelagic zones (Kagezi pelagique) depth between 10 and 50 m and at a distance from the coast between 500 m and more than 10 km in the rainy season (from September 17 to 25, 2011), (Figure 1).

2.2 Fish sampling methods

Fishing was facilitated by a motorized canoe. However, five techniques were used: Gill net fishing (7.5 cm mesh), beach seine fishing (5 cm mesh), hook line fishing, Fiknet fishing and basket fishing. At this level, we noted that only gillnet and beach seine fishing produced more or less satisfactory catches. The beach seine, thanks to its small mesh size, allowed us to increase the capacity to capture fish at different stages of growth during the rainy season and the dry season. At the laboratory level, the measurement of the total length, the standard length and the height of the body were taken on the specimens using the Mititoyo brand caliper before the dissection which was carried out using thin forceps. The opening of the fish was made ventrally starting half a centimetre from the anus which is located in front of the anal fin using the fine scissor until stopping 1 cm from the end of the jaw, being careful not to progress by spreading the scissors too far so as not to damage the underlying organs. The total length (TL) in cm being the horizontal distance from the front end of the fish to the end of the folded caudal fin; that is, the maximum length of the fish in the horizontal direction (Plisnier, 1988) [12]. The stomach of each specimen was weighed using a KERN EG brand scale (620g). The stomachs were in turn opened using sharp needles and their contents were diluted in a petri dish containing water. The different prey fractions will be analysed under an Olympus CX43 microscope. The identification of different prey ingested by this fish species was carried out at the generic or specific level based on determination works described by several authors (Toshihiko, 1983, Mpawenayo, 1996; Fernando, 2002; Ramade 2003, 2005; Isumbisho *et al*., 2006) [13-18].

The quantitative analysis of the diet will be carried out according to the work of Lauzanne (1976, 1972), Hyslop (1980), Plisnier and Micha (1988) [5, 19-21], the following methods of which will be used:

A) Occurrence method

It consists of counting the number of stomachs (Na) where a category A of food is represented. This number is expressed as a percentage of the total number (Nt) of non-empty stomachs analysed. This index is defined by the following formula:

I0 = Na /Nt * 100.I0: occurrence index; Na: number of stomachs where the relevant food category found; Nt: total number of non-empty stomachs.

B) Volumetric method

The volumetric method is one in which the type of food in each stomach is considered common, frequent, rare and estimated by eye in relation to the abundance and size of the animal. Each food category is assigned a number of points, and all the points earned by each food type are added together to give a percentage composition of all fish's food. Iv = PP/PPT * 100.Iv: Volumetric index; PP: Proportion of a food category considered for the entire sample; PPT: Total proportion of all food categories examined. From these last two indices, it is possible to calculate the food index using the following formula: IV = I0 * Iab/100. The AI dietary index makes it possible to determine the nature of the diet of a given fish. For AI < 10%: Prey of secondary importance; For AI between 10 and 25%: Important prey; For AI between 25 and 50%: essential prey; For AI > 50%: Largely dominant prey.

C) Food index

The dietary index (AI) makes it possible to determine the true nature of the diet of the given fish. It takes into account not only the observed quantities of each food category (Iv) or (Iab) but also their total frequency of observation (Io). This index combines the volumetric index (Iv) or abundance index (Iab). This index is calculated as follows: Ia = (Iv x Io)/100 Where, Ia is the food index, Iv is the volumetric index and Io is the occurrence index.

3. Results

In the results section we present the composition of our sampling, the diet of *Labeobarbus altianalis* for all of the samples and finally the variation in the diet depending on the size of the individuals.

3.1 Genera composition of collected fish

Figure 2 shows the evolution of genera of fish captured during the sampling period: *Oreochromis* (79%) is the most represented genus. It is followed by the genera: *Haplochromis* (8%), *Labeobarbus* (4%), *Bagrus* (4%), *Protopterus* (2%), *Clarias* (2%), *Labeo* (0.7%) and finally *Mormyrus* (0.3%).

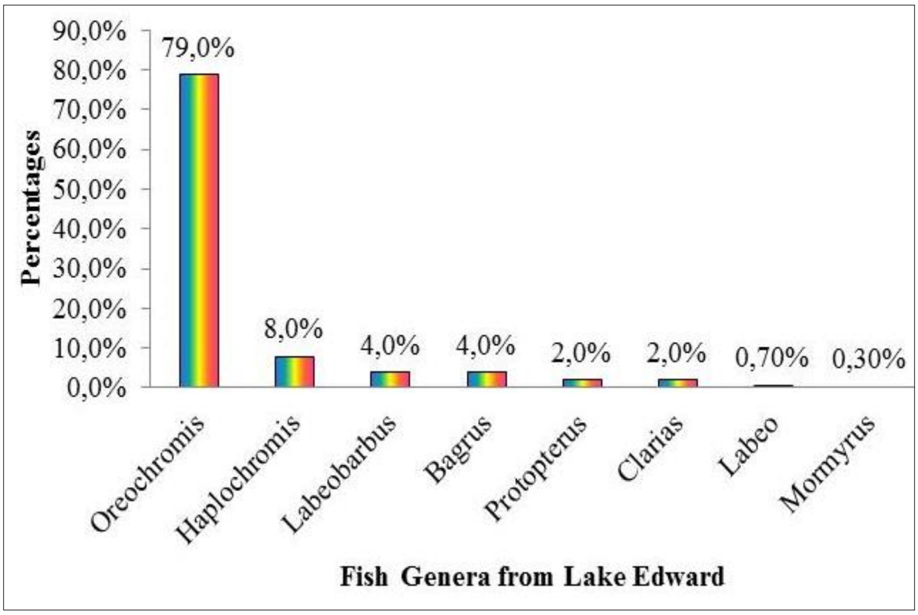

Fig 2: Specific compositions in fish genera from Lake Edward

3.2 Quantitative composition of the diet of the stomach contents analyzed

3.2.1 Occurrence indexes: Figure 3 presents the index of occurrence of stomach contents in percentages. Generally speaking, *Labeobarbus altianalis* feeds on plant debris (29%). These are followed by molluscs (18%), insects (15%), fish (14%), sand (13%), worms (5%), zooplankton (5) and finally phytoplankton (5%).

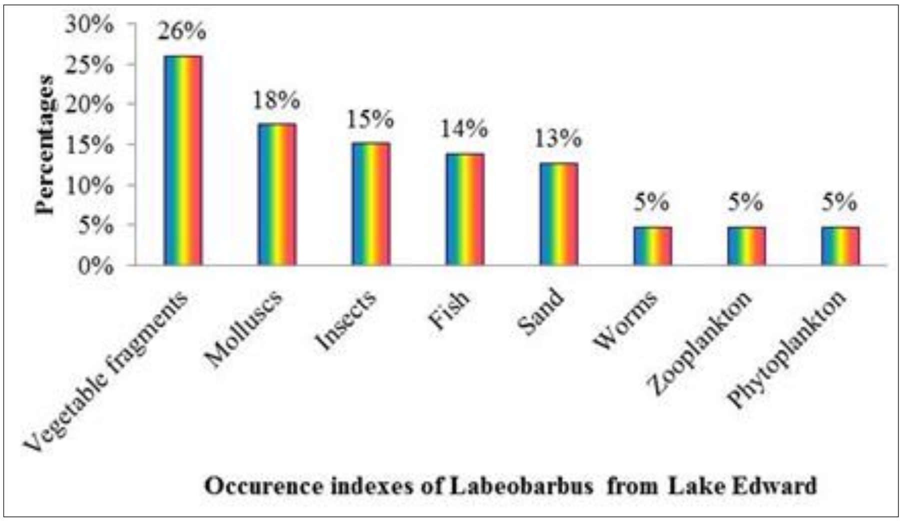

Fig 3: Occurrence indexes of *Labeobarbus altianalis* from Lake Edward

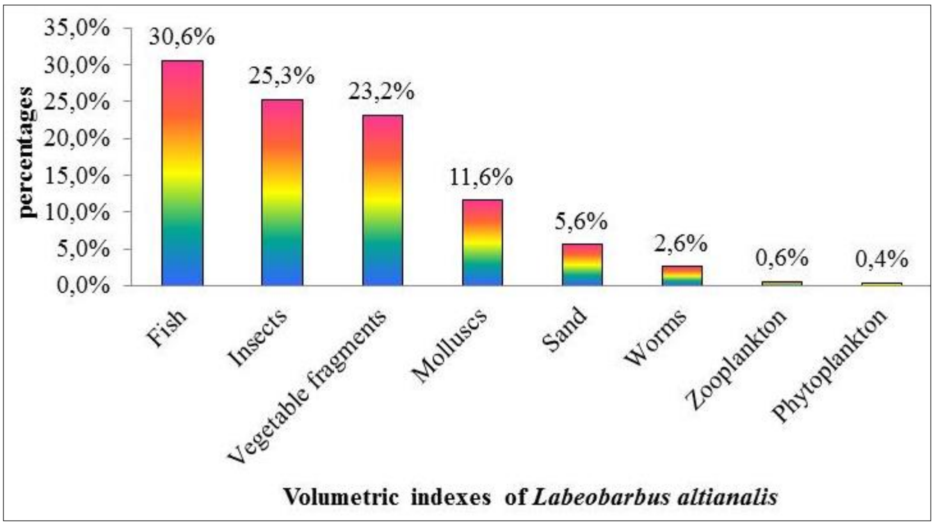

Fig 4: Volumetric Indexes of *Labeobarbus altianalis* from Lake Edward

3.2.2 Volumetric indexes: Figure 4 presents the volumetric index of the stomach contents of *Labeobarbus altianalis* from Lake Edward. Fish (AI=14.55; 30.6%) come first. They are followed by insects (AI=13.5; 25.3%), plant debris (AI=21.23; 23.2%), molluscs (AI=7.2; 11.6%), sand (AI=2.5; 5.6%), worms (AI=0.45; 2.6%), zooplankton (AI=0.1; 0.6%) and finally phytoplankton (AI =0.1; 0.4%).

2.2.3 Food indexes: It appears from Figure 5 that *Labeobarbus altianalis* primarily prefers to feed on vegetable fragments (40.0%), followed by fish (28.3%) and insects (25.5%). Secondly, it completes its diet with molluscs (4.7%), sand (0.8%), worms (0.4%), phytoplankton (0.2%) and finally zooplankton (0. 2%).

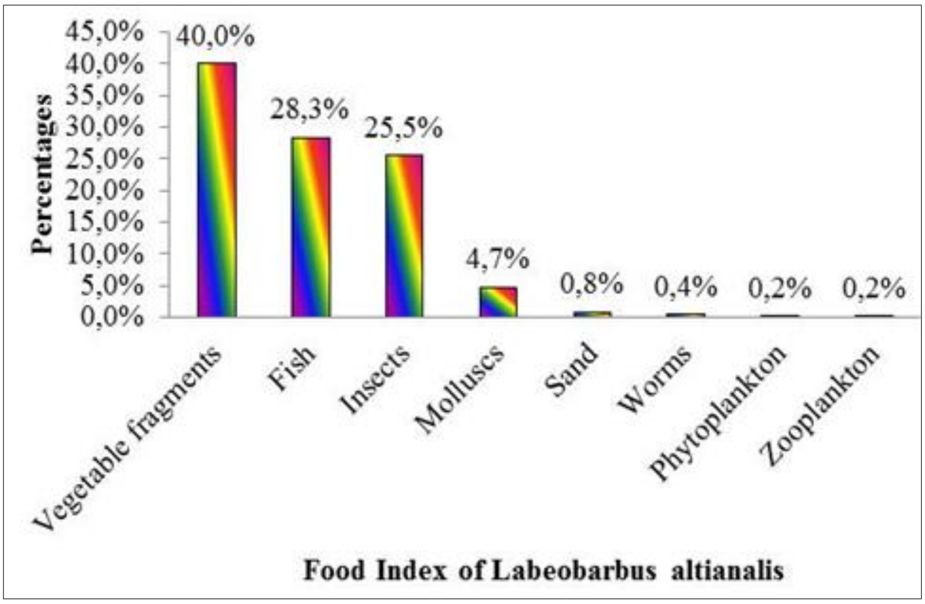

Fig 5: Food Indexes of *Labeobarbus altianalis* from Lake Edward

3.3 Variation in diet depending on the size of individuals

3.3.1 Diet of adults: From 32 to 77 cm, total length: *Labeobarbus altianalis* of large size

3.3.2 Occurrence indexes in adults of *Labeobarbus altianalis:* It appears from figure 6 that large *Labeobarbus altianalis* feeds primarily on vegetation fragments (40.0%), fish (28.3%), insects (25.5%) and molluscs (4.7%). Secondly it absorbs sand (0.8%), worms (0.4%), zooplankton (0.2%) and phytoplankton (0.2%).

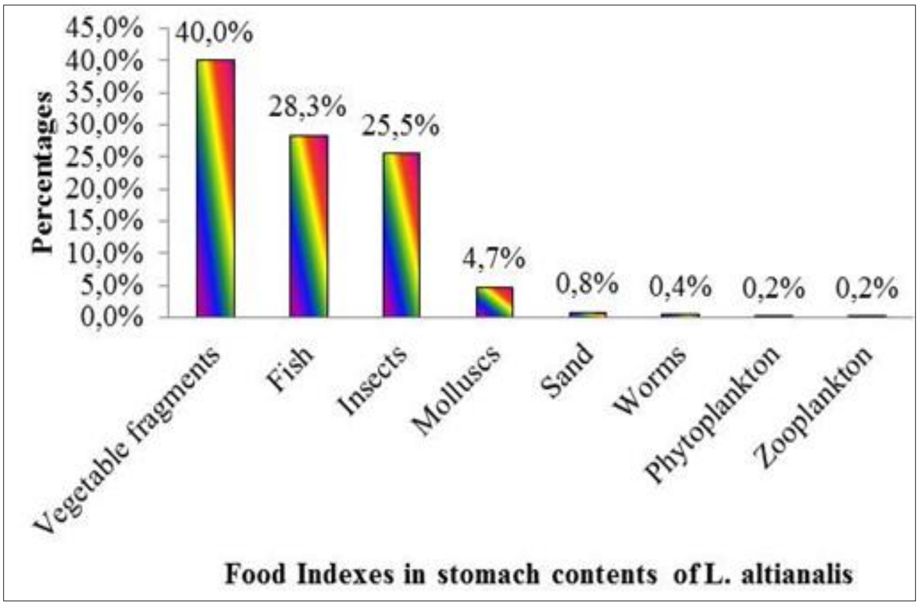

Fig 6: Diet of adult *Labeobarbus altianalis* from Lake Edward

3.3.3 Variation in diet depending on the large size of individuals (From 32 to 77 cm in total length)

3.3.3.1 Occurrence Index: Based on the index of occurrence of labeobarbus altianalis adults, it appears that to figure 7 that large *Labeobarbus altianalis* feeds primarily on plant debris (35.0%), fish (33.6%), molluscs (17.5%) and insects (5 .8%). Secondly, it absorbs sand (4.4%) and worms (2.9%). Phytoplankton (0.0%) and zooplankton (0.0%) were not found.

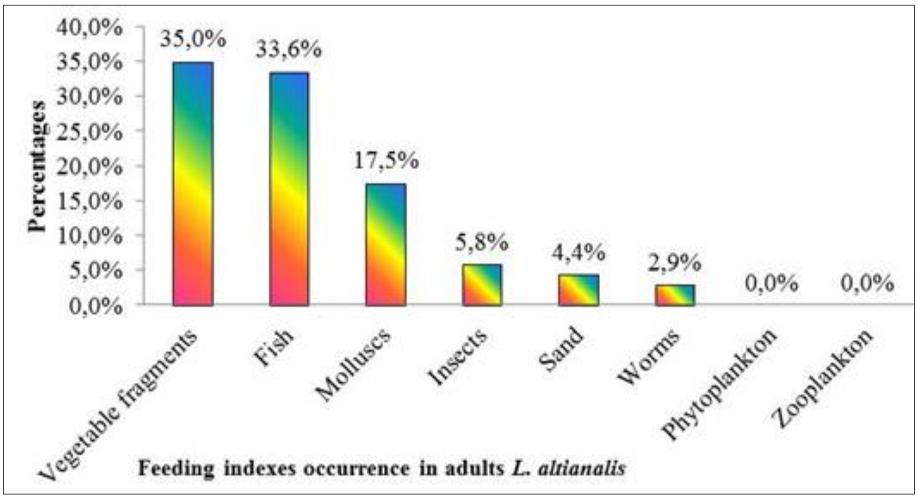

Fig 7: Adult feeding occurrence index *Labeobarbus altianalis*

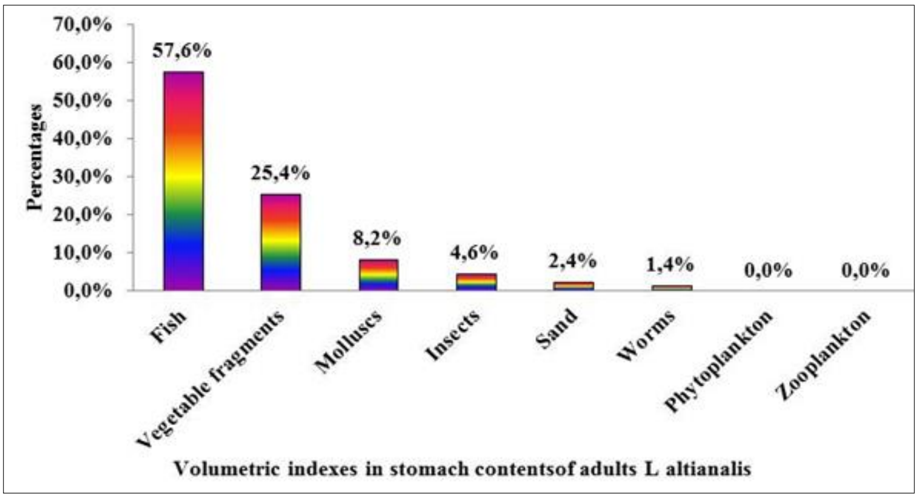

Fig 8: Volumetric indexes in the stomach contents of adults *Labeobarbus altianalis*

3.3.3.2 Volumetric indexes of adults *Labeobarbus altianalis*

Figure 8 reveals that *Labeobarbus altianalis* of size between 32 and 77cm in total length feeds on fish (57.6%) in first position. Next come plant debris (25.4%), molluscs (8.2%), insects (4.6%), sand (2.4%), worms (1.4%). Phytoplankton and zooplankton were not found.

3.3.3.3 Dietary indexes in the stomach contents of adults *Labeobarbus altianalis*

Figure 9 shows the dietary indices of Labeobarbus altianalis adults. Fish [(AI=53) (64.1%)] which have a dietary index greater than 50 are classified as largely dominant prey. They are followed by plant debris [(AI=24.6) (29.7%)], which have a food index of between 10 and 25, and are therefore qualified as important prey. Molluscs [(IA=3.9) (4.7%)], followed by insects [(IA=0.8) (1.0%)], sand [(AI=0.3) (0. 4%)] and worms [(IA=0.1) (0.2%)] which have dietary indices lower than 10 are qualified secondary prey. Phytoplankton (0.0%) and zooplankton (0.0%) were note found in the stomach contents of this stage.

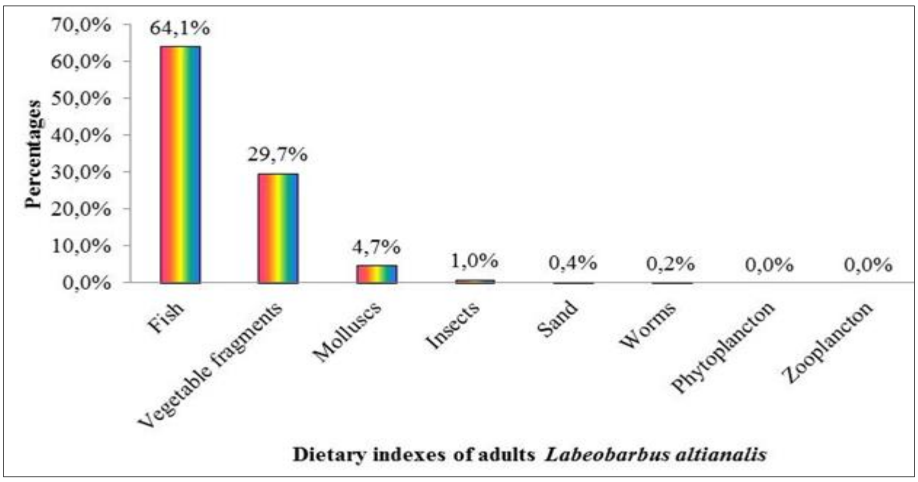

Fig 9: Dietary indexes in the stomach contents of adults *Labeobarbus altianalis*

3.3.4 Variation in diet depending on the large size of individuals From 10 to 31 cm total length young *Labeobarbus altianalis*

3.3.4.1 Occurrence Indexes in the stomach contents of young *Labeobarbus altianalis*

Figure 10 reveals that young *Labeobarbus altianalis*, measuring between 10 and 31 cm in total length, feed on insects [(Io=95.4) (22%)], vegetable fragments [(Io=86.4) (20%)], sands [(Io=81) (19%)], molluscs [(Io=77.3) (18%)], phytoplankton [(Io=36.4) (8%)], zooplankton [(Io=36.4) (8%)] and worms [(Io=27.3) (6%)]. Fish are not present in the stomach contents of *Labeobarbus altianalis* of this size.

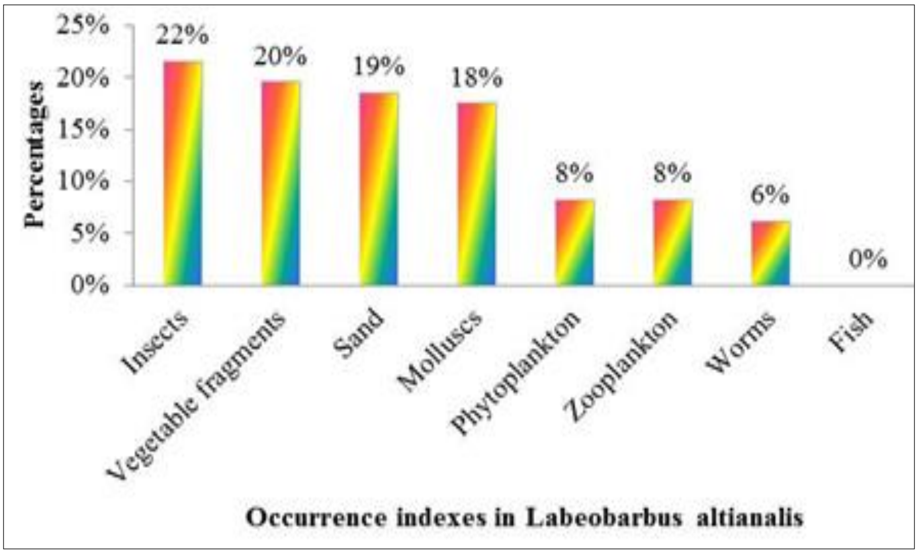

Fig 10: Occurrence Indexes in the stomach contents of young *Labeobarbus altianalis*

3.3.4.2 Volumetric indexes in young *Labeobarbus altianalis*

It appears from Figure 11 that young *Labeobarbus altianalis* primarily feed on insects (48.6%), vegetable fragments (20.4%), and molluscs (15.5%). They supplement their diet with sand (9.3%), worms (4.1%), zooplankton (1.3%) and phytoplankton (0.8%). Fish are not included in their diet at this stage.

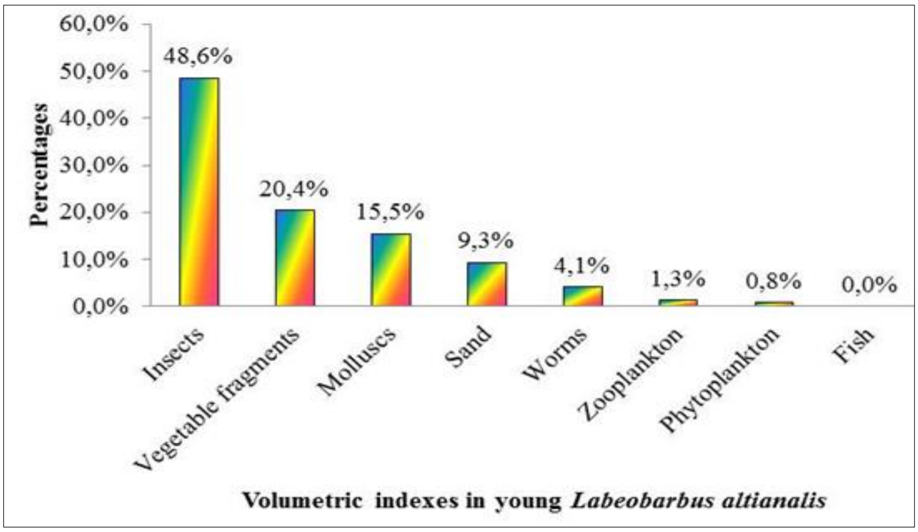

Fig 11: Volumetric indexes in young *Labeobarbus altianalis*

3.3.4.3 Dietary indexes of young *Labeobarbus altianalis*

Figure 12 shows that phytoplankton [(IA=0.3) (0.4%)], zooplankton [(IA=0.5) (0.6)], worms [(IA=1.1) (1.3%)], and sands [(AI=7.6) (8.9%)] are prey of secondary importance given their food indexes (IA) lower than 10. Molluscs [(AI=12) (14.0%)] and vegetable fragments [(AI=17.6) (20.6%)] are important prey, given their food indexes between 10 and 25. Finally insects [(AI=46.4) (54.3%)] are the essential prey because their food index is between 25 and 50. Fish (0, 0%) are absent in the stomach contents of young *Labeobarbus altianalis.*

3.3.4.4 General overview of the diet of *Labeobarbus altianalis*

From the above, the diet of adult *Labeobarbus altianalis* is made up of fish in greater quantities (+++) while young *Labeobarbus altianalis* feed mainly on insects (+++). *Labeobarbus altianalis* adults, like the young, supplement their diet with vegetable fragments (++), (Figure 13).

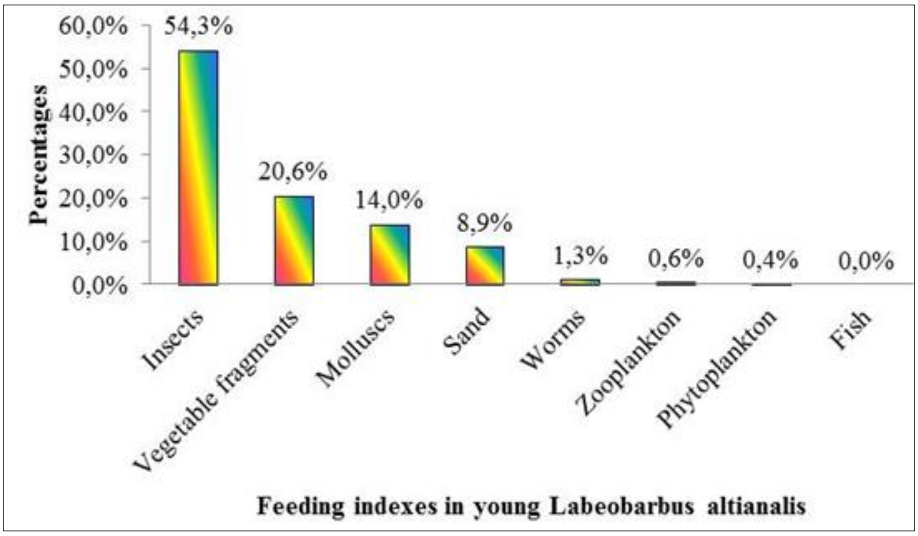

Fig 12: Dietary indexes of young *Labeobarbus altianalis*

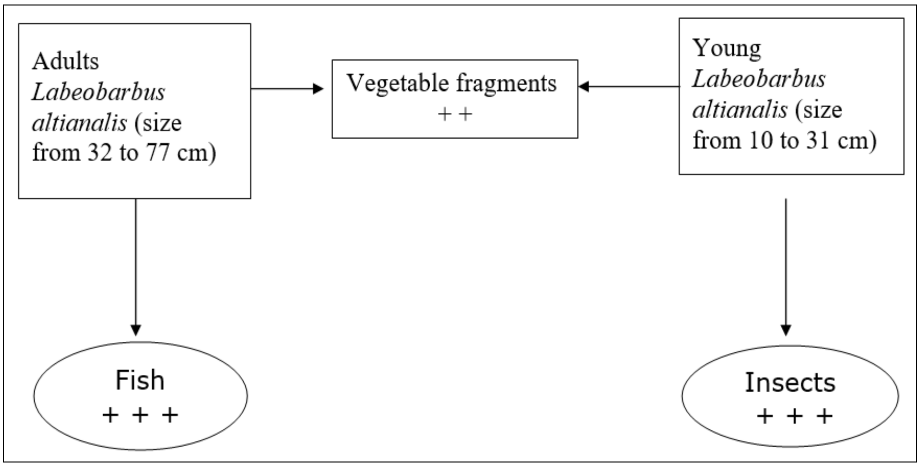

Fig 13: General overview of the diet of *Labeobarbus altianalis*

4. Discussion

In general, eight different foods were found in the stomach contents of *Labeobarbus altianalis*. These include phytoplankton, zooplankton, plant debris, fish, molluscs, worms, sand and insects. These results are not very different from those obtained by Lebrun (1938) Okito *et al*., (2017) [1, 22] who noted the presence of phytoplankton, zooplankton, plant debris, fish, insects, crustaceans and molluscs. The results of Désiré et Kakule (2006) [23] on the stomach contents of *L. altianalis*, in ponds, do not deviate from these results either. He had found mosquito larvae, insects, annelids, grains of sand, fish and plants. The results of Lausanne (1976) [5] who had also worked on the variation in the diet according to the size of Labeobarbus from Lake Chad, had insinuated that fish of the *Labeobarbus* genus, current it is reaching a large size have a diet composed of aquatic larvae insects, molluscs, debris of higher plants and seeds, copepods, Ostracods, filamentous algae, shrimps, crabs, terrestrial insects and small fish. According to this author, in Lake Chad, young Labeobarbus altianalis feed on insect larvae and small crustaceans as well as plant debris. As for our samples from Lake Edward, the occurrence index revealed that *Labeobarbus altianalis* feeds more frequently on plant debris, usually molluscs, fish, insects, and supplements its diet with worms, sand, zooplankton and phytoplankton. However, we found that this distribution changes with the size of the fish: For large fish, the occurrence index revealed that they frequently feed on fish and plant debris while for small fish: Insects, plant debris, sand and molluscs are frequently consumed foods. Here we notice that the diet of small fish is more diverse than that of large fish. Fish which are among the prey frequently consumed by large Labeobarbus altianalis are not part of the diet of small fish; this means that only large Labeobarbus altianalis are capable of consuming the fish. Note that plant debris is generally consumed by Labeobarbus altianalis of small and large sizes.

For the rest of the foods, it is not contradictory to say that they are more frequent in the stomach contents of young *Labeobarbus altianalis* than in those of adults *Labeobarbus altianalis*. For example the case of molluscs which were present 77.3% in the stomach contents of young *Labeobarbus altianalis*, represented only 48% in the stomach contents of adults *Labeobarbus altianalis*. Furthermore, it should be noted that in the stomach contents of adults *Labeobarbus altianalis*, phytoplankton and zooplankton were absent. This is explained by the fact that these foods are small. The volumetric index reveals almost the same reality mentioned for the previous case. Indeed, fish were absent in the stomach contents of young *Labeobarbus altianalis*, whereas they were preferentially consumed by adults *Labeobarbus altianalis*. As for the rest of the foods, in most cases they occupy a considerable volume in the stomach contents of young *Labeobarbus altianalis* than in those of adults *Labeobarbus altianalis*. This is for example the case of insects which

occupied a volume of 48.6% in the stomach contents of young *Labeobarbus altianalis*, but occupied only 4.8% of the volume of the stomach contents of adults *Labeobarbus altianalis*.
The calculation of the food index revealed that for adults *Labeobarbus altianalis*, fish are largely dominant prey given their food index greater than 50 %; while they are absent in the stomach contents of young *Labeobarbus altianalis*.
However, for young *Labeobarbus altianalis*, insects are essential prey while vegetable fragments and molluscs are important prey, because their food index is between 10 and 25%. The same is true for vegetable fragments in adults *Labeobarbus altianalis* whose food index is 53%. The rest of the food is prey of secondary importance given that their food index is less than 10 %. Note, however, that in general, phytoplankton and zooplankton are absent in the stomach contents of adults *Labeobarbus altianalis*.

5. Conclusion

Our work focused on the study of the diet by size class of *Labeobarbus altianalis* in Lake Edward. To do it, two field surveys were carried out, one during the dry season (from July 27 to August 1, 2011) and another during the rainy season (from September 17 to 25, 2011). Several fishing techniques were used, namely: The 7.5 cm mesh size sleeping gill nets; 5 cm mesh size beach seine; finest; basket nets and hook lines. But only the sleeping gill nets and the beach seine provided us with appreciable catches.
Eight different foods were found in the stomach contents of *Labeobarbus altianalis* in general: Phytoplankton, zooplankton, vegetable fragments, fish, molluscs, worms, sand and insects. The calculation of dietary indices for all of our samples proved that plant debris and fish are important prey and that the rest of the food is secondary prey. By studying these same indices by size class, we proved that for young *Labeobarbus altianalis*, insects are essential prey, vegetable fragments and molluscs are important prey while phytoplankton, zooplankton, worms and sand are secondary prey. Fish are absent in the stomach contents of young *Labeobarbus altianalis*.
As for adults *Labeobarbus altianalis*, we found that fish constitute the largely dominant prey and that vegetable fragments are important prey while molluscs, insects and sand are prey of secondary importance. Note here that phytoplankton and zooplankton were absent in the stomach contents of adults *Labeobarbus altianalis adults*.

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