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Brief evaluation of the current state of fish stocks landed by artisanal fishing units from the extreme northwest part of Lake Tanganyika

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Abstract
Lake Tanganyika fisheries frame survey conducted in 2011 by Lake Tanganyika Authority (LTA) revealed overfishing activities due to an increase of fishing-gears/boats number and a decrease in fish catches. Lakewide annual fish production was estimated between 165-200 thousand tons, but reliable catch and effort estimations along Congolese waters are stilling rare. This study is the synthesis of catches evolution of three Artisanal Fishing Units (AFUs): catamaran/liftnet, trimaran/appolo and gillnet from northwestern Lake Tanganyika to increase fisheries conservation and management measures. Fishing-data from government services and other stakeholders from 2008-2013 were collected and recycled in a database. Total production for three AFUs was 1,628.2 t/6 years, with 62% of *Stolothrissa tanganicae*. But 50.6% were landed on Kilomoni landing site and 51% were achieved by catamarans. Annual average of CPUE was 245.4 kg for catamarans and 104.7 kg for gillnet/fishing-night. The fishermen average number per fishing-night with appolos was higher compared to catamarans and gillnets, with differences in study sites. The relevance of this paper increases substantially that of fishing management if compared against earlier fragmented studies in the areas.

Keywords: Fishing Unit, Northwestern, Lake Tanganyika, catch evolution, management

1. Introduction

Lake Tanganyika fishery sector is mainly based on pelagic production constituted by 90% of two sardine's species: *Stolothrissa tanganicae* (Regan 1917) and *Limnothrissa miodon* (Boulenger 1906) and four Lates species, principally *Lates stappersii* (Boulenger 1914) [1, 2, 3, 4, 5, 6, 7, 8]. There are three main fishery types in Lake Tanganyika including industrial fishery which has disappeared in the lake, artisanal and traditional fisheries. Artisanal fishery supplied industrial ones and is specialized in the exploitation of the pelagic stocks by supporting important commercial activities of vital protein source for millions people living in the four neighboring countries of Lake Tanganyika [9, 10, 11]. Traditional fishery focuses on demersal and littoral fishes [12, 13, 14]. The most operational AFUs in the lake are two light-fishing techniques namely catamarans (liftnet and appolo) and non-light-fishing of gillnet units [15]. However, lakewide annual fish production is estimated between 165,000 and 200,000 t [16, 11] but there are inaccurate fish production estimations especially in Congolese waters of the lake though there are hardly fish protein demands [17, 18]. The period from the late 1990s to 2010 was characterized by a lack of fisheries data on Lake Tanganyika and consistent data were only collected by Burundi during this time period [18]. Some estimates indicate a total annual catch of 34,000 t [19, 20] and 90,000 t [12, 21] in Congolese waters where numbers of catamaran and trimaran (appolo) asset were estimated at 2,169 and 396 respectively belonging 51,625 fishers [11]. No recent production estimations have been reported in Congolese waters and there is lack of fishing-data even if catch declines due to intense fishing activities (overfishing) were recorded since 1990s in the lake [22, 11, 18]. This was already demonstrated in Burundian waters (9, 23) and pelagic fisheries could be at their maximum pressures in these areas and some Congolese important human population centers as Uvira. At the extreme northwest part of Lake Tanganyika there are lacks of accurate fishing-data available especially in Uvira areas to judge these fishing pressures and to support fishery management. Fishing-data collections are not regular, that is difficult to fishery managers in sustainable fishery planning. Using available fishing-data from different services in Uvira from 2008 to 2013, this article investigates current state of fishery resources and develops plans and management difficulties encountered by giving complementary further important propositions to all stakeholders for sustainable fishery management in Lake Tanganyika.

2. Materials and methods

Lake Tanganyika is bordered by four countries: Burundi, Tanzania, Zambia and the Democratic Republic of the Congo (DRC), the part of which extends over 14 800 km² (45%) of the lake's surface and 795 km (43%) of its perimeter. Lake Tanganyika has a maximum depth of 1470 m and an approximate surface area of 32,600 km2; it is the second deepest lake in the world and the second largest lake in Africa, in terms of surface area [10, 18]. The total volume of the lake is estimated at 18,900 km^3 making it the second largest freshwater reservoir in the world, representing approximately 17% of the world's surface freshwater [18]. As its only outflow, the Lukuga River, leads up to the Congo River, the lake is regarded as one of the sources of the Congo system. Lake Tanganyika offers vital resources including food, household water and transportation to an estimated 10 million people in the riparian countries, its economic impact reaching far inland [16]. The present study covered the extreme northwest parts of Lake Tanganyika in Uvira territory (03°28'S, 29°17'E) which contributes the highest fish production in the fish flow of the Democratic Republic of Congo. This area is bounded in the north by Ruzizi floodplain, in the south of the territory of Fizi, in the west by Mitumba Mountains and in the east by Lake Tanganyika, which gives it the opening to Burundi, Tanzania and Zambia zones from Kalundu harbor. The whole area is characterized by two morphological groups including a sandy coastal plain to 775 m and the eastern slopes of Mitumba Mountains. This region has a tropical humid climate characterized by an alternation of wet and dry seasons. The annual rainfall and temperature averages are respectively around 800 mm and 24 °C. The region is actually subject of intense increasing human population pressures, living mainly from agriculture, livestock, small trades, but mostly by fishing activities in Lake Tanganyika.

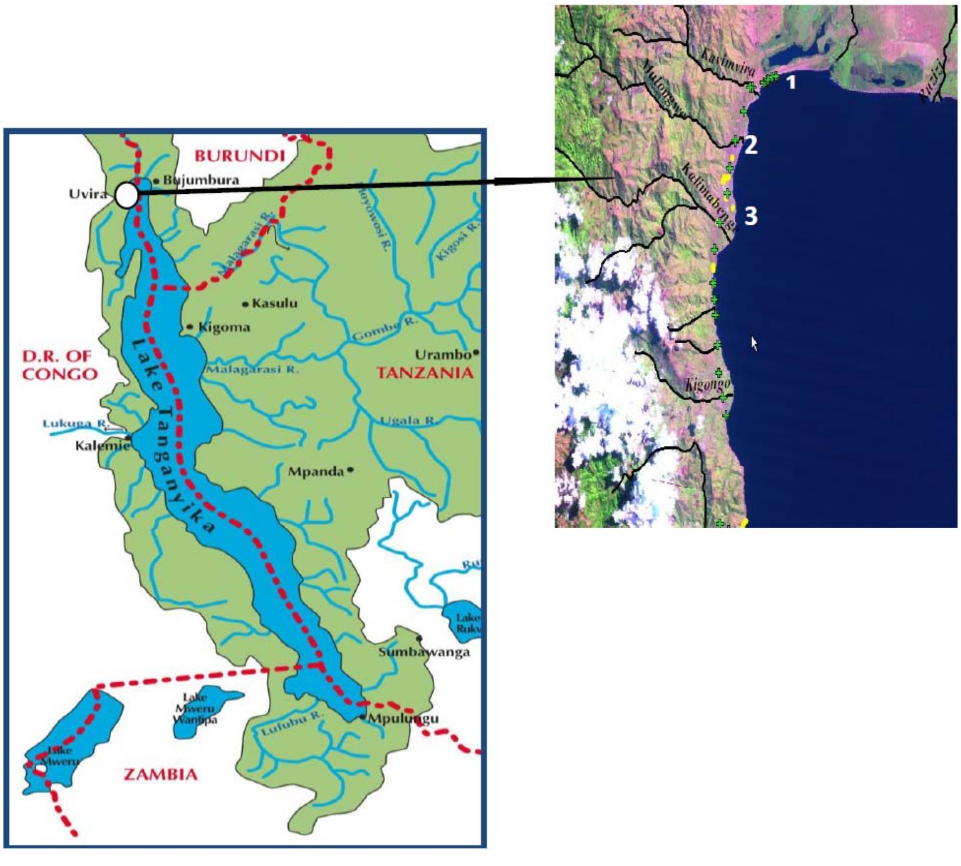

Fig 1: Northwestern Part of Lake Tanganyika with sampling stations. The large circle = Uvira; 1=Kilomoni, 2=Mulongwe and 3=Kalundu (© picture-google satellite and Jorgensen *et al*. 2005).

Both fishing-data the documentary and the exploitation approaches of six consecutive years (from 2008- 2013) were used to properly assess trends of fish stocks exploited by three major artisanal fishing units from Uvira study sites. We performed the integration of fishery statistical data collected by multiple efficient systems of government of D R Congo in Uvira (Centre for Hydrobiological Research, Agriculture, fisheries and livestock offices and Environmental services). Most of fishing-data were only available completely from 2008 to 2013 and were collecting in morning (from 7-10 hours) on only three main landing sites namely Kilomoni, Mulongwe and Kalundu were selected randomly (Figure 1). Daily total catch (kg) of two clupeids (*S. tanganicae and L. miodon*) and one Latid (*L. stappersii*) were weighted and the number of AFUs per landing site of Uvira indicated. The catch per unit effort (CPUE) was calculated by dividing the total catch (TC) by the number of active AFUs. Data analyzed concerned the commercial total catches, fishing-effort and AFUs activities. After collecting, these data were entered into a statistical database and were, therefore, subject of analysis using Excel 2007 and SPSS 16.0 softwares to assess the relationship between catch per year, per unit and per effort by site. Comparisons and averages, percentages were made to strengthen these analyzes and inter-annual catches evolution between landing sites, study years or changes in fishing effort per fishing unit by using these softwares.

3. Results

The global catch analyzed during the study period was estimated to 1,628 t/6 years (average CPUE: 245.4 kg) for all AFUs and was indicating inter-annual variations (F= 20.1, p <0.0001) (Figure 2). Short increasing peaks were observed in 2009 (302 t) and 2012 (320 t). The lowest annual catches were recorded in 2010 (263 t) and 2013 (169 t). And these latest years saw their mean CPUE dropped, moving from 319.6 kg in 2012 to 169.4 kg in 2013.

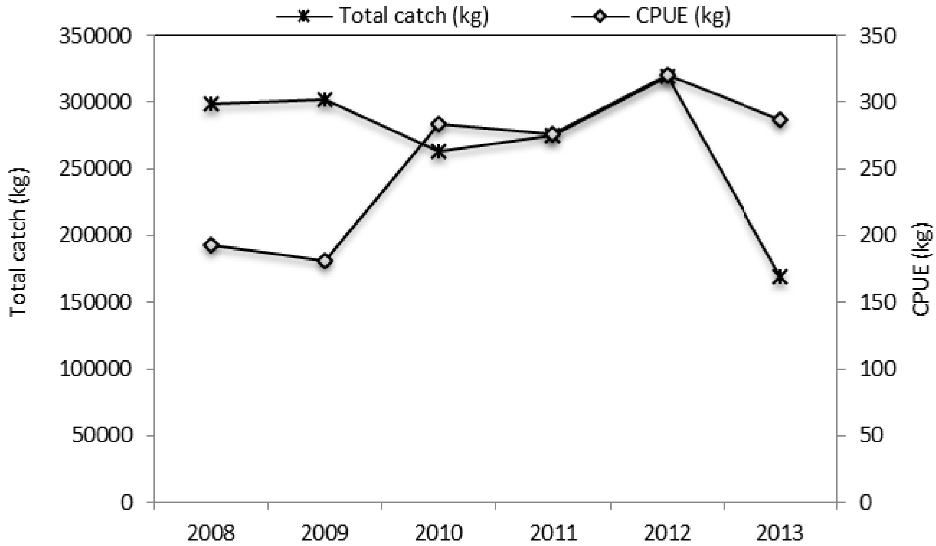

Fig 2: Total annual catches and CPUE evolution of artisanal fisheries from 2008 to 2013 in Uvira.

The total catches landed in Uvira by three major AFUs types were indicated the decreases for gillnet recorded to 265 t (16.3%) during the study period (Table 1). Catamarans/liftnets and trimarans/appolos were recorded 51 and 32.7% of total catches respectively. The great catches landed by catamarans were due to their higher number (2851). But the averages of appolos CPUE (425.6 kg) were higher compared to other two AFUs for the six studying years.

The total catches analyzed were showing differences between the three AFU types (F=190.4, p <0.0001), but in generally decreases were observed year-to-year although large peaks in 2012 and low in 2013 were observed (Figure 3A). Mean gillnet CPUE were around 10.4 kg in 2012 and 12 kg in 2013 and tended to increase in the three landing sites studied while those of catamarans were hovering around 50 kg since 2008 (Figure 3B).

Table 1: Distribution of total catches and CPUE mean (± SD) by AFUs in Uvira from 2008 to 2013.

AFUs	TOTALCATCH (kg)	% TC	CPUE (kg)	n
Catamaran/liftnet	830 398	51,0	291,3±523,4	2 851
Appolo/trimaran	532 854	32,7	425,6±771,3	1 252
Gillnet	264 918	16,3	104,7±251,4	2 531
Total	1 628 170	100,0		6 634

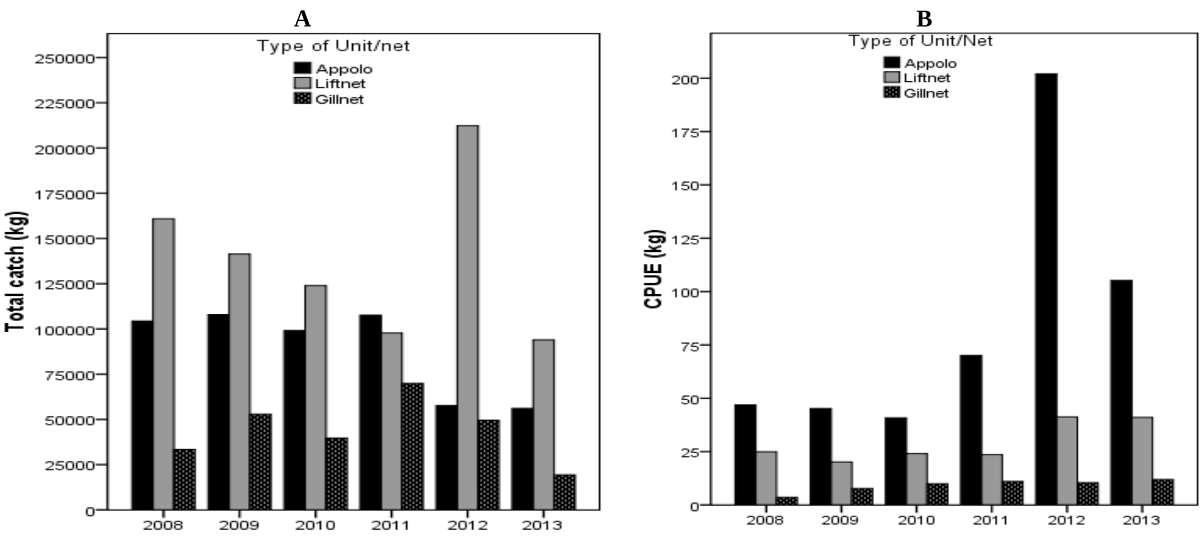

Fig 3: Annual catches (A) and CPUE (B) evolution by AFUs in Uvira from 2008 to 2013.

More detailed examination of total catches by pelagic species type showed that *S. tanganicae* was most dominant (62%), followed by *L. miodon* (17%) and *L. stappersii* (11.6%) in Uvira sites (Table 2).

Table 2: Variations of the total catches and CPUE (± SD) by species between 2008 and 2013 in Uvira.

Pelagic species/group	Total catch (kg)	% TC	CPUE (kg)	n
S. tanganicae	1 007 370	61,8	358,9±560,1	2807
L. miodon	282 788	17,3	130,8±291,7	2162
L. stappersii	188 648	11,6	148,4±563,5	1271
young *Clupeidae*	130 942	8,0	501,7±898,4	261
young *L. stappersii*	18 422	1,1	138,5±262,7	133
Total	1 628 170	100		6634

For the three pelagic species, the annual catch trends were indicating decreases in general even if *S. tanganicae* were showing large peaks in the catches (Figure 4).

S. tanganicae was much landed by catamarans (Figure 5). Total catch and CPUE by species were lower for young *L. stappersii* while they were higher for young Clupeidae according to the three operational AFUs examined in Uvira waters of Lake Tanganyika.

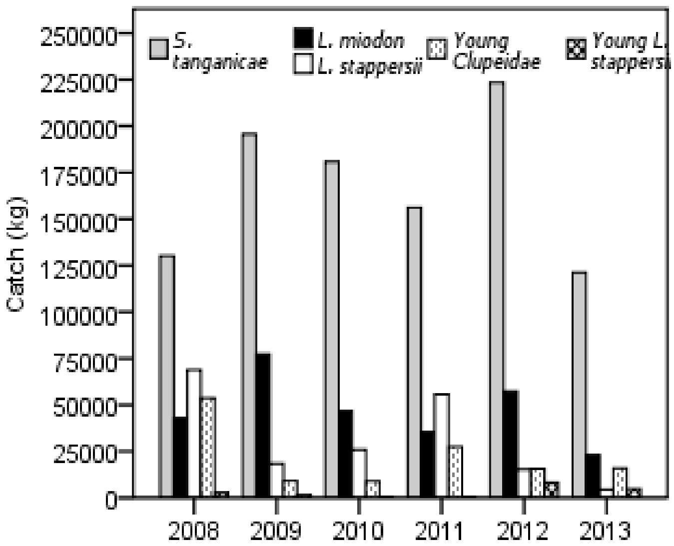

Fig 4: Annual catches evolution by species in the northwestern Lake Tanganyika from 2008 to 2013.

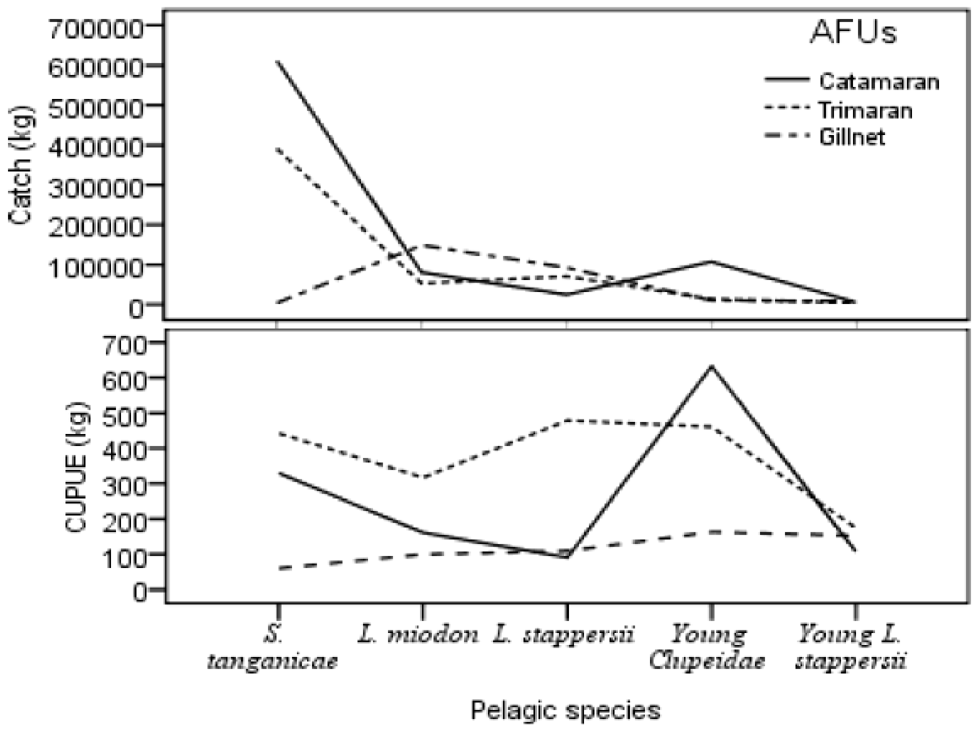

Fig 5: Total annual catches and CPUE by species and AFUs between 2008 and 2013 in Uvira.

The total catches variation in landing sites were indicated that about half of total catch was recorded and marketed in Kilomoni site (50.6%); followed by Mulongwe (40%) and Kalundu (9.5%) respectively (Table 3).

The active number of fishermen per AFU in the three landing sites was higher for appolos per fishing-night and was generally showing declines since 2008 (Figure 6). The number of fishermen using gillnets indicated a slight increase.

Table 3: Total catches and CPUE (±SD) between 2008 and 2013 in the main landing sites off Uvira.

Landing site	Total catch (kg)	% TC	CPUE (kg)	n
Kilomoni	823 322,0	50,6	444,3±665,5	1853
Mulongwe	650 483,0	40,0	255,2±556,8	2549
Kalundu	154 365,0	9,5	69,2±113,6	2232
Total	1 628 170,0	100,0		6634

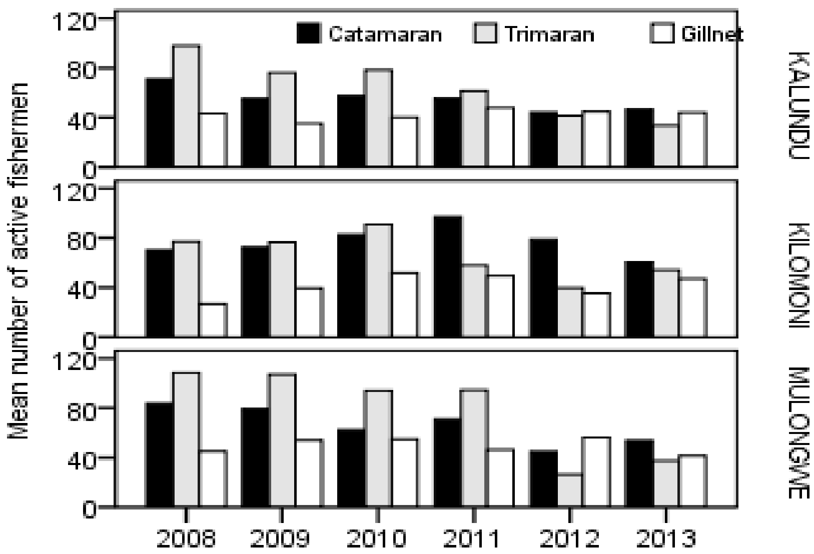

Fig 6: Annual distribution of the average number of fishermen using different AFUs types in Uvira from 2008 to 2013.

Detailed results of AFU annual effort were indicated that gillnets were higher (15 units) in the three landing sites off Uvira. The number of trimarans was declined year-to-year and that of catamarans was stable throughout the study period (Figure 7).

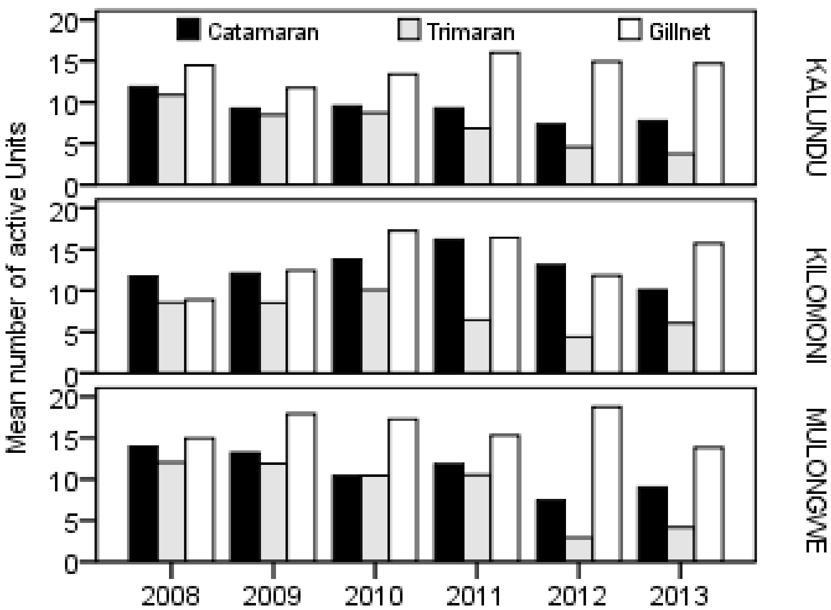

Fig 7: Annual variation of average number of active units in the landing sites off Uvira number from 2008 to 2013.

4. Discussion

Lake Tanganyika artisanal fishery sector is complex, diversified in species, fishing-gears as well as business findings and imply several communities whose various fishing practices (individual and collective) lead to interest' conflicts due to fish protein high demands in the region. However, fish catch decreases resulting in increased uncontrolled fishing effort on Lake Tanganyika [18] indicate needs in increased fishery monitoring and sustainable fishing programs implication in neighboring countries is actually essential. In general, fish production in the lake may virtually vary, therefore, each year depending on each neighboring country and according to AFU types and their respective investments or effort as well as the composition of fish species targeted as our results reported. Total fish production for each riparian country is 20,000 t in Burundi, 60,000 in the DR Congo, 80,000 in Tanzania and 10,000 in Zambia [10, 11]. But, fishing in the pelagic zone of Lake Tanganyika in general could be at its maximum pressure especially in Burundi waters where they capture virtually 100% of available biological resources [9]. In Congolese waters of the lake, production is poorly understood and fisheries data are not collected continuously. Available fishing-data in these parts of the lake are mostly not sufficient to illustrate fishing pressures on pelagic stocks in areas where large scale illegal fishing techniques are done. It is difficult, however, to get accurate fishing-data because of a lack of reliable fishery statistic programs in the DR Congo, Tanzania, and Zambia [18]. So, our results are strongly reported that fish catch trends in Uvira waters (DR Congo) are similar to those in Burundi and pelagic fishing is certainly in trouble though that point of view need more illustrate data (e.g. fishery, limnology, climate, socioeconomic, etc.). In this part of the lake, therefore, it is reported a lack of standardization systems at the national and local levels in the collection of statistical data; a lack of coordination and planning of fishing-programs; a lack of qualified and trained staff to collect reliable fishing-data [24, 25, 21]. Most of fishing-data are not valuable and useful directly; the consequences are illegally fishing techniques and that should heckle all stakeholders in Lake Tanganyika fishery sector to implement both the rational fishery programs and the sustainable action strategies.

The total artisanal fish production analyzed in our results was 1,628 tons for six consecutive years (average: 271 t/year) in Uvira areas with major peaks in 2012 and minor in 2013. That production varied annually and the general trends have shown decreases since 1992 in the study areas if compared to the results of Coenen [21] estimated to 805 t/year. The large decreases in total annual catches is remarkable and there was already reported in 1993-1994 that fishing pressures are the most cause in Bujumbura and Uvira waters, followed by Mpulungu areas in Zambia [11, 9, 26]. However, catches evolution on Lake Tanganyika may be linked to several factors evolutions, including biological and socioeconomic. An increase of sardine stocks mortality rate combined with their CPUE decrease in Uvira were seen as being of an overfishing pressure [26]; therefore considerable effort. Thus, changes in the annual catches in Uvira areas can be due to an exceptional abundance of pelagic fish stocks, but variations in catches are primarily related to the artisanal fishing effort gradual increases. 27,535 active fishing units are recorded in Lake Tanganyika and majority are reported in Congolese waters: 13,596 units in which 2,169 are catamarans and 396 trimarans/appolos [11]. By strengthening our results, recent data in the lake show that catamarans and appolos are in large numbers in Burundi, DR Congo and Tanzania waters [11, 18]. The average number (effort) of gillnets per fishing-night was superior compared with catamaran (11) and trimaran (8) in each landing sites visited in Uvira. There is still unclear to determine the optimum fishing effort or the fishing capacity for each AFU type to enhance sustainable management of artisanal fishery in the study area. Thus, artisanal fishing in the lake is facing monitoring and managing problems, particularly in the northwestern part of the lake where the use of destructive fishing-gears is common [15] and the conservation value still important [27]. To achieve that, this article advises fishery management measures to not consider increasing the number of fishing units or artisanal fishermen in Lake Tanganyika, especially in the Congolese (Uvira) and Burundian waters. Total catch landed and marketed by each AFU in Uvira for six consecutive years examined, indicated that catamarans represent 51% and trimaran 32.7%. Gradual decreases are showing annually in the CPUE of catamarans ranging to 50 kg per fishing-night throughout the study period, previously evaluated to 143.8 kg [12, 13, 22]. That fact is right also in Burundian waters where the CPUE have gradually decreased to 50 and 80 kg per fishing-night for catamarans and appolos respectively [23]. We have noted that appolos landed high CPUE compared to catamarans. But CPUE decreases are generalized; more pronounced for appolos if we must refer to respective variable costs and investments made by each AFU, most significant for appolos. Total catches (16.3%) and their respective CPUE were lower for AFUs using gillnet during the study period. These gillnet catches are, however, to be taken with precaution because gillnet units have not always permanent landing site to market their fish catches and are often not reported accurately on the beach. Gillnet fishermen can sell all or a party of their catches anywhere in lacustrine waters before reaching to the main market on the coast. This is further demonstrated difficulties for fishery managers on Congolese shores of Lake Tanganyika to collect good fishing-data and to evaluate the catch per fishing unit. The gillnet units are most common and large scale used in the study area even these illegal nets are laws prohibited. Their number and their potential impacts are remaining to be investigated in detail to assess fish resources in the lake. It is important, therefore, to adopt monitoring measures from the local authority and other stakeholders in the sector by facilitating the investigators work in the registration of fishing-data. This will be effective by increasing communities' participation and surveillance, by strengthening their local Beach Management Units (BMU). The gillnet units, most originally developed in Lake Kivu for introduced sardine fishing [28], have currently increased enormously in a relatively short period in the northwestern Lake Tanganyika because of their simple fishing methods (passive gear less expensive), their low investments (between $US 1,500 to 2,000) and rate of charges (no light-attraction or more canoes/fishermen). With high fishing pressure, by both the light-fishing and gillnet on the clupeid and *L. stappersii* resources, the catches of *L. stappersii* with gillnet units could be mostly composed with immature and juvenile fishes although that need to be more clarified by examining the fish caught. Furthermore, *L. stappersii* additional threat is here posed and the outcome of pelagic small scale fisheries is bleak in Lake Tanganyika if further efforts are not undertaken now. We should not implement a technique well adopted in Lake Kivu, mainly colonized by introduced *L. miodon* without predator and which are posing no problem there while the danger becomes real in Lake Tanganyika in the presence of Lates species.

The annual catch evolution of pelagic species fished by landing sites during the study period was showing that *S. tanganicae*, following by *L. miodon* is most dominant. That same observation was previously reported by previous studies in Lake Tanganyika [9, 17, 29, 7]. But, it is reported that *S. tanganicae* is generally dominant species in the north while the catches of *L. stappersii* are important in the south parts of the lake [30, 31, 32, 33]. The pelagic species catch may also be related to the number of AFU (effort) used during the study period. Hence, AFUs targeted-species are differing in their sizes or weight, landed volume and have not same market-value or food-preferences in the study area [3]. Our result explained the rapid proliferation of gillnet AFUs in the study sites according the targeted-species composition. So, gillnets AFUs are more active in the capture *L. stappersii* of different sizes fished the day as well as the night. Biological detailed reviews of each fish species according to the three AFU types and respective fishing-gears still to be important to know properly in order to determine or propose optimum number of each AFU to be tolerated by resources of each pelagic species in the lake. Catamarans were more active in sardines (ndakala) catches (*S. tanganicae* and *L. miodon*). The proportions of juvenile fish species landed according to three AFUs in each study sites were also appearing most significant in our results to illustrate fishing pressures. Thus, pelagic fish examinations paralleled to each fishing-gear impacts are remaining not well elucidated to strengthen fisheries management in Lake Tanganyika as demonstrated in Lake Kivu [28].

The total annual catch evolution in three main landing sites visited has indicated that Kilomoni (50.6%) and Mulongwe sites (40%) are excellent fish flowing sites in the region. These sites are playing important socio-economical roles as fish market flow and fishing inputs. Lake Tanganyika fishery strategies should focus their efforts on improving rehabilitation and equipment in these landing sites for both favorable fish processing and marketing conditions and fishermen well-being in the lake.

5. Conclusions

The annual AFU catches evolution from fishing-data of Uvira from 2008-2013 indicated intense fishing activities which are requiring, at medium-terms, monitoring and management rapid actions. There is a lack of more accurate fishing-data to improve resource management along Congolese coasts of Lake Tanganyika where integrated programs are needed. *S. tanganicae* is more common landed and marketed species while the illegal gillnet fishing-technique is most common in Uvira areas and laws prohibited fishing method, that effect threatens *L. stappersii* stocks. Catamarans and trimarans presented catch decreases annually, but their optimum effort numbers per species and per site are highly needed to strengthen sustainable fish stocks management in Lake Tanganyika. Finally, national and regional strategies should deal first local communities/fishermen initiatives and this will lead to contribute to increased food security in the lake basin.

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